EFFECT OF SALINITY OF DRINKING WATER AND DEHYDRATION ON THERMOREGULATION, BLOOD AND URINE COMPOSITION IN NUBIAN GOATS

By

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DEDICATION

To my Parents, Brothers, Sisters and to my best friends
Dr. Kamal Hassan Ali and E.n Mutasim Maroof.

ABSTRACT

The studies were performed to investigate the effects of salinity of drinking water, state of body hydration and seasonal changes in the tropical thermal environment on physiological responses of Nubian goats.

In experiment 1, the effects of salinity of drinking water (0.8, 1.2, 1.6, and 2% NaCl) on physiological responses of Nubian goats have been investigated in winter and summer. Tr was not affected by salinity of drinking water, RR during summer at 2:30 p.m, was significantly higher with all groups receiving saline water compared to respective groups receiving tap water. The values of Tr and RR were higher during summer and showed significant diurnal changes in both seasons.

In both seasons, water intake by treated groups was significantly higher compared to respective control group values and the increase in NaCl concentration from 0.8 to 1.6% NaCl in drinking water increased water consumption by the goats but at 2% NaCl, water intake decreased. The intake of NaCl in drinking saline water increased significantly with increase in NaCl concentration. The high concentrations of NaCl (1.6 and 2%) in the drinking water resulted in a significant decrease in food intake of the goats. The mean body weight change was significantly lower in the group receiving 1.6% NaCl during winter compared to respective control group.

The packed cell volume (PCV) level during summer was significantly lower for groups receiving 1.2 and 1.6% NaCl in drinking water compared to respective groups offered tap water. The highest value of PCV for treated

groups was recorded during winter in the group offered 2% NaCl in the drinking water. The highest values of Hb for treated groups were recorded during winter in the group offered 2% NaCl in the drinking water. The plasma glucose level was not affected by salinity of drinking water in both seasons, but in winter the mean plasma glucose level for control as well as treated groups was slightly higher compared to values obtained in summer.

The serum total protein (Tp) and albumin (Alb) concentrations increased significantly by gradual increase in NaCl concentrations in drinking water during winter. In both seasons, Tp and Alb were higher for the groups offered 1.2, 1.6 and 2% NaCl compared to respective control groups. In both seasons, the serum urea level was significantly lower in the groups receiving high concentrations of NaCl (1.6 and 2%) in the drinking water compared to the lower concentrations.

In both seasons, the serum concentration of Na was significantly higher in all groups offered saline water compared to the respective control groups. The increase in NaCl concentration in the drinking water increased the serum Na level significantly during summer. The serum K level in both seasons decreased significantly with increasing NaCl concentration in the drinking water. In both seasons, the serum Mg level was not affected by gradual increase in the concentration of NaCl in drinking water.

In both seasons, there was a significant increase in urine urea level with increasing NaCl concentration in the drinking water. The urine urea values in both seasons were significantly higher in treated groups compared to respective control groups. In both seasons, there was a significant increase in urine Na concentration with increasing NaCl concentration in the drinking

water. The urine Na values were higher signifacntly in treated groups compared to respective control groups during winter. The urine K level was increased significantly with increasing NaCl concentration in the drinking water during winter. The urine Mg levels in both seasons were higher in treated groups compared to respective control groups. There was a significant increase in urine Mg concentration with increasing NaCl concentration in the drinking water during summer.

In experiment 2, the effects of saline water drinking (1.2% NaCl) and the state of body hydration on the physiological responses of Nubian goats have been investigated in wet summer. The combined effect of saline water drinking and dehydration significantly increased Tr of the goats. Following rehydration Tr decreased in the treated goats. RR was not affected significantly by the group receiving saline water (1.2% NaCl) compared to respective control group values, but during the first day of dehydration there was a significant increase in RR for both control and treated group. While on the second day of dehydration there was a significant decrease in RR for both control and treated groups.

The salinity of drinking water significantly increased water consumption by the treated group compared to respective control group values. For both control and treated groups, water intake by the goats in the first day of rehydration was significantly higher compared to the normal hydration value. Dehydration resulted in a marked decline in food intake of both control and treated groups, but this decrease in food intake was significant only in the group offered tap water. 1.2% NaCl in drinking water

had no effect on food intake by the goats compared to control group (tap water).

The salinity of drinking water (1.2% NaCl) did not influence significantly the PCV and Hb concentration during experimental phases, but water deprivation increased the PCV and Hb concentration in both groups. On rehydration, the PCV and Hb concentration returned to the normal hydration level on the second day. The plasma glucose level tended to decrease during the dehydration period.

The combined effect of saline water drinking water and dehydration significantly increased the serum Tp, Alb and urea level of the goats. Serum Tp and Alb levels of the treated group were not significantly different compared to respective control group values. The serum urea level increased significantly for treated group compared to respective control group values.

The serum concentration of Na was significantly higher in the treated group compared to the respective control group value during the normal hydration period, while the K level was significantly lower in the treated group compared to the respective control group value during the normal hydration and rehydration periods. The serum Mg level was significantly higher in the treated group compared to the respective control group value during the second day of dehydration and the rehydration period.

The results presented in this thesis for the Nubian goats were discussed and compared with previous studies on the goat and other domestic animals.

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CHAPTER ONE

INTRODUCTION

1.1 Goats in the world and Sudan

The vast majority of the world's grazing land occurs in seasonal environment which is characterized by marked fluctuations in resource abundance. Among the most dynamic are the arid and semi-arid regions of the tropical belts, where extended periods of dryness (6 to 8 months) are punctuated by erratic rainfall and brief eruptions of forage production (Silanikove, 2000). For ruminants grazing in these regions, the maintenance of water balance and energy metabolism is challenging to productivity as there is a close relationship between water requirement and food intake (Macfarlane and Howard, 1972).

The arid and semi-arid zones comprise 55% of the area of sub-Saharan Africa and support 50-60% of the livestock and 40% of the people in that area. About 88% of the world goat populations (610 million head) are located in Asia and Africa, mostly (80%) in the tropics and subtropics (Knight and Garcia, 1997).

Sudan is divided into three separate natural regions, ranging from desert in the north, covering about 30 percent of all Sudan, through a vast semiarid region of steppes and low mountains in central Sudan, to a region of vast swamps and rain forest in the south. Sudan has a tropical climate. Seasonal variations are most sharply defined in the desert zones, where winter temperatures as low as 4°C are common, particularly after

sunset. Summer temperatures often exceed 40°C in the desert zones, and rainfall is negligible. High temperatures also prevail to the south throughout the central plains region, but the humidity is generally low. In the vicinity of Khartoum the average annual temperature is about 27°C; and annual rainfall, most of which occurs between mid-June and September, is about 250 mm. Equatorial climatic conditions prevail in southern Sudan. In this region the average annual temperature is about 29°C, annual rainfall is more than 1,000 mm, and the humidity is excessive.

According to Arab Organization for Agricultural Development (AOAD - 2000), the goat population in Sudan is estimated at about 37 million head. They are classified into four types: Nubian, Desert, Nilotic dwarf and Taggari. The productivity of indigenous goats was improved by up-grading of the local breeds by crossbreeding with the highly productive exotic breeds. In 1976, three exotic temperate breeds, Saanen, Toggenburg and Anglo-Nubian have been introduced into the Sudan for improving milk and meat production (Khalafalla and Suleiman, 1990). Also in 1993, in Khartoum state, male and female Saanen breed were improved to be used in up-grading the local breeds of goats for milk production.

1.2 General features of adaptation of goats to harsh environment

Ruminants are widespread in hot, arid regions. This demands adaptation to large circadian temperature fluctuations and recurrent periods of food and water shortage (Kerstin, 2005).

In these regions goats are relatively much more numerous than cattle and frequently more numerous than sheep (Devendra, 1990); it has been consistently shown in different countries and environmental conditions that goats indigenous to harsh environments perform better than other domesticated ruminants (Devendra, 1990; King, 1983; Shkolnik and Silanikove, 1991). Low body mass and low metabolic requirements of goats have been important assets in minimizing their maintenance and water requirements (Silanikove *et al*., 1980, 1986ab, 1993). The reduction of metabolism allows goats to survive even after prolonged periods of severe limited food availability. Moreover, a skilful grazing behaviour and efficient digestive system enable goats to attain maximal food intake and maximal food utilization in a given condition (Tisserand *et al*., 1991).

The physiological features of goats which are responsible for superior digestion capacity include large salivary glands, large absorptive area of their rumen epithelium, and a capacity to rapidly change the volume of the foregut in response to environmental changes. A positive interaction has been reported between the better recycling rate of urea and a better digestion of such food in desert goats (Maltz *et al*., 1981; Silanikove, 1984).

The rumen plays an important role in the evolved adaptations by serving as a huge fermentation vat and water reservoir (Silanikove, 1994). The water stored in the rumen is utilized during dehydration, and the rumen serves as a container which accommodates the ingested water upon rehydration. The rumen, salivary glands and kidney coordinate functions in the regulation of water intake and water distribution following acute dehydration and rapid rehydration (Silanikove, 1994).

In the tropics goats depend on tree-leaves and shrubs (browse) which ensure a reliable and steady supply of food all year around, albeit, of a low to medium quality. Although goats and sheep are mixed feeders, under mixed forage conditions, goats consume a larger proportion of browse than sheep and use it more efficiently (Devendra, 1990). Unlike sheep and cattle, which do not eat leafy material during the green season, browse constitutes at least 40% of the forage selected by goats at all times. This pattern of diet selection, however, is not compatible with maximizing milk yield. Indeed, selection of goats in harsh Mediterranean environments was most certainly based on breeding success and lifetime performance (Silanikove, 2000).

In arid areas, the sources of drinking water contain high concentrations of salts with NaCl as the main constituent (Gihad *et al*., 1993). Underwood and Settle (1999) noted that the amount of sodium, chloride and other minerals variable from none in some streams to high supplies usually from deep wells or bores. Furthermore, Cummings (2002) reported that all natural waters contain some dissolved salts, and Chy and Phillips (1995) noted that approximately one-third of the earth's land surface is affected by salinity, sodicity and aridity in various combinations.

Goats are known to be particularly useful to resource poor people in semi- arid and arid zones, where they can sustain themselves on sparse forage and extreme climatic conditions (Misra and Khub, 2002). Moreover, the goat has been used extensively as an experimental animal, and much of what is known about milk synthesis and associated mechanisms relates to the goat. The goat's milk is superior to the cow milk, because of higher

concentration of short chain fatty acids which can be easily digested (Devendra and Burns, 1983).

Various reports on responses of ruminants to water deprivation in harsh environments have been published for West Africa (Aganga *et al*., 1988), East Africa (Schoen, 1968) , Southern Africa (Sibanda *et al*., 1997; Adogla-Bessa and Aganga, 2000), and there is limited information regarding the effect of water salinity (Assad *et al*, 2002) . However, there are no published reports on the effects of drinking saline water and dehydration in adult Nubian goats.

1.3 Thermoregulation

The ability to maintain a stable body temperature while exposed to a range of varying environmental elements is called thermoregulation. It is important to all animals because each species has a preferred body temperature at which functioning is optimal. The external conditions include temperature, vapour pressure, air velocity, and insulation and other factors that affect the temperature of the skin. Cold-blooded animals regulate their body temperature by selecting an appropriate external environment. Warm-blooded animals also rely on physiological mechanisms which can produce or dissipate heat (Polk *et al*., 1995).

There are two control systems for temperature regulation in endothermic animals. The behavioural system involves conscious voluntary acts to adjust physical characteristics of the air-skin interface (moving the animal out of the hot sun or into the shade) while the physiological system consists of involuntary responses of the body that generate or dissipate heat.

In accordance with the first law of thermodynamics, a general heat balance equation for an animal can be written as

$M - W = C + Rn + K + \lambda Er + \lambda Es + J$

In this equation

M = rate of heat gain by metabolism.

W= rate of external work done.

C = rate of heat loss by convection.

Rn = net rate of heat loss by radiation.

λEr = rate of heat loss by evaporation from the respiratory tract.

λEs = rate of heat loss by evaporation from the skin surface.

K = rate of heat loss by conduction.

J = rate of storage of thermal energy in the body.

In the natural environment, the radiation environment is complex; an animal receives direct and diffuse short-wave radiation as well as thermal radiation from the ground and atmosphere as illustrated in Fig.1 (Gates, 1968).

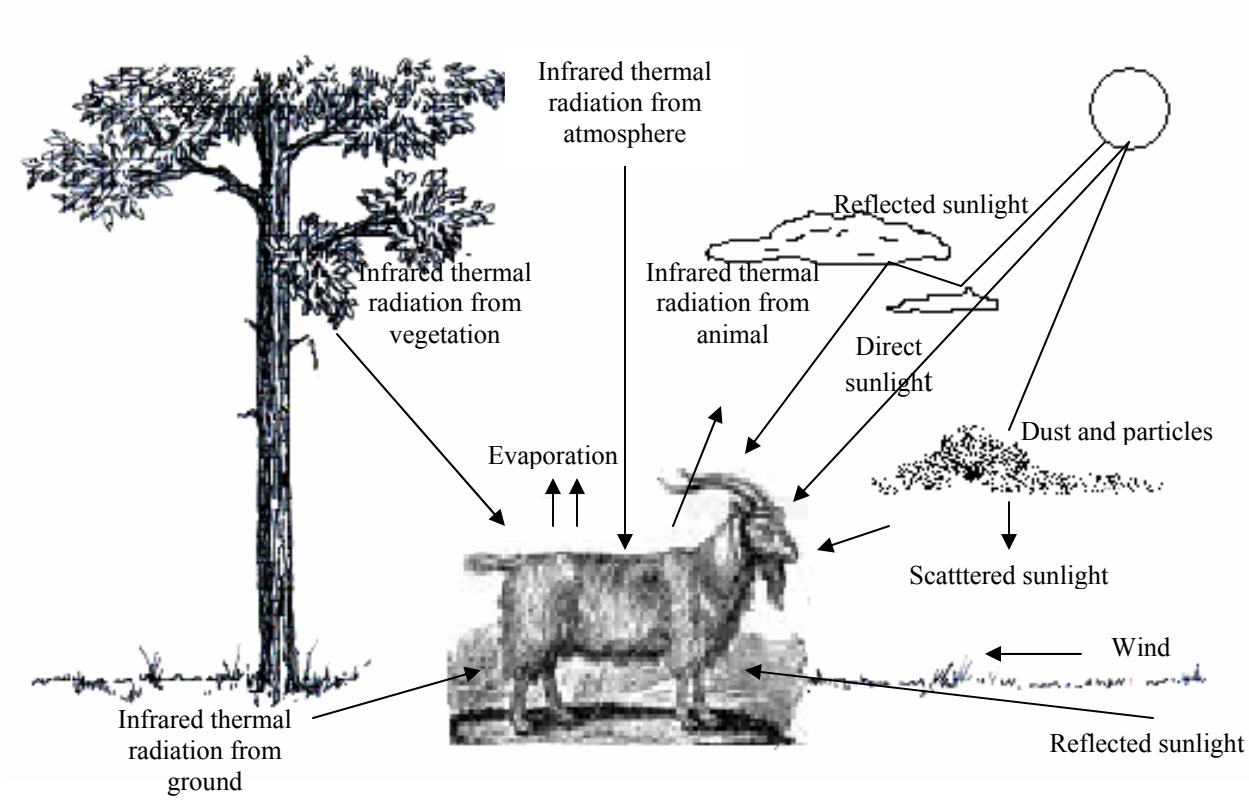


Fig. 1: The streams of energy flow to and from an animal in its natural environment (Adapted from Gates, 1968).

The physiological system for thermoregulation operates like an automatic control system that responds to surrounding environment. The body temperature is regulated at a set reference temperature, and temperature sensors throughout the body respond to the central controller in the medial preoptic/anterior hypothalamic region of the brain stem, which then adjusts heat production and loss accordingly (Fig.2). Stefan and Jessen (1978) reported that cooling the anterior hypothalamus in goats increased heat production; however, the increase was smaller when the posterior hypothalamus was cooled. With increased heat load, the responses include cutaneous vasodilatation and panting, inhibition of adrenaline and thyroxine secretion, and increase in adrenal corticoid secretion (Cooper, 1966; Crial and eric, 1971).

Heat acclimation and acclimatization cause an increase in body temperature and a decrease in thyroid activity in goats (Yousef, 1984), cattle (Thomson, 1973), sheep (Valtorta, 1982), llamas and (Elnouty *et al*., 1978). Thomson (1973) suggested that in sheep, high ambient temperatures seem to have a direct influence on decreasing thyroid activity, In contrast, low ambient temperatures increase thyroid function in cattle (Yousef and Johnson, 1965) and pigs and llamas (Yousef and Jonson, 1967).

Cortisol is recognized as a calorigenic agent in many mammalian species (Yousef and Johnson, 1967). Olsson and Dahlborn (1989) reported that Plasma cortisol increased in lactating goats at high ambient temperature. Christison and Johnson (1972) reported that short term exposure to heat

increased plasma cortisol in cows. On the other hand, long term exposure to heat decreased cortisol turnover rate and plasma levels. Yousef and Jonson

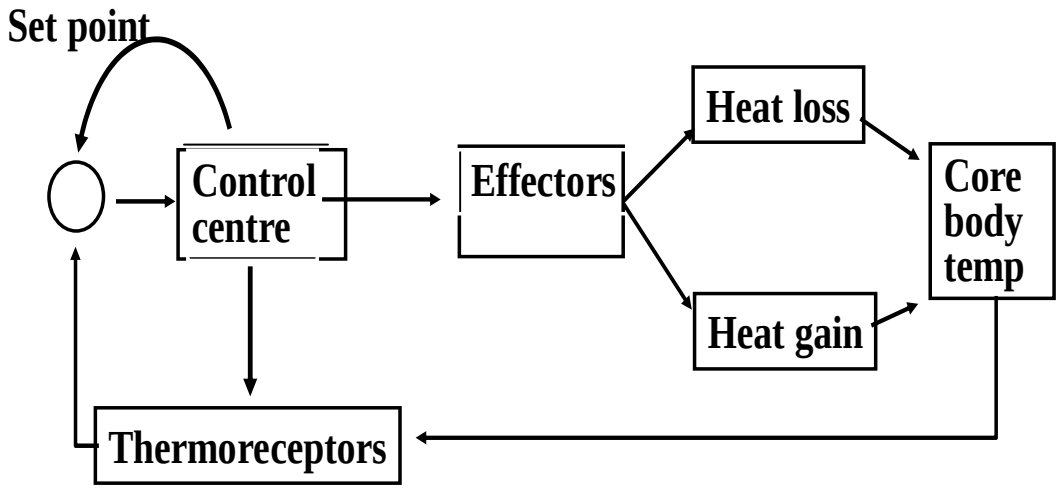


Fig. 2. Body temperature as a balance of heat loss and heat gain.

(1967) suggested that the reduced plasma levels of glucocorticoids which occur during heat acclimation constitute a beneficial regulatory mechanism for reducing the animal's heat production. The effect of cold exposure on glucocorticoids was studied in newborn calves; exposure to −4°C had no effect on plasma glucocorticoids and exposure to −18ºC caused either an increase or a decrease in this level (Khan *et al*., 1970). Furthermore, acute cold stress had no detrimental effects on shorn sheep when the animals were supplemented with exogenous glucocorticoids (Panaretto and Ferguson, 1969).

1.4 Water balance and metabolism

Water is obviously important for mammals, and the amount required depends on that needed for the maintenance of normal water balance and to provide for satisfactory levels of production. The normal body water content of the goat varies with age, amount of fat in the body, and environmental temperature. It would be expected to exceed 60 percent of the body weight and 75 percent of the nonbony tissues. Shkolnik *et al*. (1980) have shown that some goats, such as the black Bedouin of the Negev and Sinai desert goats, have the capacity to store as much as 76% of their body weight of water. A dynamic balance between water gain and water loss usually maintains, within narrow limits, the amount of total body fluid in ruminants (Andersson, 1978). The presence of adequate water in body tissues is an

essential prerequisite for the normal maintenance of life, and water is a fundamental constituent of all living cells (Aganga, 1992). Goats are among the most efficient domestic animals in the use of water, approaching the camel in the low rate of water turnover per unit of body weight (Maloiy and Taylor, 1971; Macfarlane and Howard, 1972). A comparison of water balance by Maradi goats and Yankasa sheep is presented in Appendix (A_1). When goats feed on dry forages and when water is lacking, the efficiency of reproduction will be reduced (Brown and Lynch, 1972; Lynch *et al.,* 1972). Suboptimum water intake will result initially in reduced feed intake, then reduced performance and gradual starvation. Acute problems result when goats are unable to maintain water balance or control body temperature.

1.4.1 Water sources

The water needs of animals are satisfied from three major sources: free drinking water, water contained in food, and metabolic water produced by oxidation of organic nutrients (NRC, 1981). Giger-Reverdin and Gihad (1991) reviewed the main factors affecting free water intake of goats. Goat are similar to other ruminants and water intake is related to taste factors, physiological status, dry matter intake, live weight, level of milk production and environmental factors.

The first two sources (free drinking water and water contained in food) are of major concern in the management of livestock, although in periods of negative energy balance, when depot fat and tissue protein are being utilized, metabolic water would be important. Goats are able to consume a significant amount of water at a single drinking session (Wilson,

1989). In black Bedouin goats, a species adapted to the arid deserts of Sinai region, water intake can reach as high as 45% of body weight without haemolysis of the red blood cells. This response is related to the rumen acting as a water store preventing water passing directly into the blood stream by reducing water flow into the lower gut thus allowing water to be absorbed over an extended period of time. This response also prevents unnecessary water and salt loss via urine. Mean values for drinking water intake by African ruminant livestock are given in Appendix (A_2).

Water contained in feed is extremely variable. It may range from a low of 5% in dry grains to about 90% in young fast-growing grasses. In addition, the amount of dew or precipitation on the grass at the time of grazing is subject to wide fluctuations. In the case of swine and poultry, diets are blended from dry ingredients and intake of water in a feed accounts for about 10% of the total feed intake (NRC, 1981).

The catabolism of 1 kg of fat, carbohydrate, or protein produces 1190, 560, or 450 g of water, respectively. Metabolic water is important to all animals, particularly those residing in dry environments (Church *et al*., 1974). As a consequence of drought, animals produce metabolic water during periods of body weight loss. A goat losing 1 kg of body weight per week, a common live weight loss during seasonal summer droughts on annual pastures in southern Australia (McGregor 1984, 1985, 1998) will generate about 130 g of metabolic water per day.

1.4.2 Water losses

There are four main avenues of water loss: urine, faeces, evaporation and lactation. Goats and sheep are regarded as having a more efficient renal system which reduces water loss compared with temperate and Zebu cattle (Wilson 1989). Aganga (1992) reported that Maradi goats lose less water in urine than the Yankasa sheep (Appendix $A_{1)}$. On a water restricted diet, urinary excretion rate can usually be reduced without impairing the ability of the kidneys to excrete body wastes (Church *et al*., 1974).

In ruminants the loss of water through faeces is substantial, approximately equal to urinary losses. The high-fibre nature of ruminant diets requires proportionately more water to carry the ingesta through the gastrointestinal tract than for nonruminants (Washington, 1981). The level of fibre is not, however, sufficient reason to explain the level of faecal water. Goat faeces have 40~45% water, and sheep faeces have 60~65% water, while cattle faeces contain 75~85% water. The ability to reabsorb water in the lower gut and excrete drier faecal pellets instead of wet, loose faeces is presumably one mechanism of water conservation. The Maradi goats drank less water and produced drier faeces than the Yankasa sheep, indicating a better water conservation mechanism (Gehad, 1976; Aganga, 1992) as shown in the Appendix $A_{1.}$

Evaporative water loss for many breeds of goats and sheep is 60% panting and 40% sweating under hot dry conditions (Wilson, 1989) (Appendix A_3). In desert adapted Bedouin goats, the relative evaporative water loss is 33% respiration: 67% cutaneous. Aganga (1992) reported that Maradi goats utilized about 70% of the total water intake for evaporative cooling, while Yankasa sheep used 72% of water. Under severe stress, cattle

and other species may lose a significant amount of water through drooling (McDowell and Weldy, 1967).Water loss from the respiratory tract is extremely variable, depending on relative humidity and respiration rate. Expired air is over 90% saturated with water vapour, hence, under conditions of low relative humidity, respiratory losses are high. Conversely, losses are low when inspired air is near saturation. When respiration rate increases in response to high temperatures or other behavioural stimuli, the rate of respiratory water loss is increased. When environmental temperatures increase of from 20^0C to above 40^0C, respiration rates in East African goats increased from about 20 to over 250 breaths/minute (Maloiy and Taylor 1971). The disadvantages of panting include a risk of respiratory alkalosis, particularly in the goat (Jenkinson, 1972), and the increase in work and therefore heat production by the respiratory muscles. However, much of this work is reduced by the elastic property of the respiratory system, which has its own natural frequency of oscillation. The high respiratory rate associated with panting has the effect of keeping the system oscillating at its own resonant frequency with the minimum of muscular effort. Thus, the thermoregulatory efficiency of panting is high in such species as sheep, which show no increase in total body heat production above normal levels (Hales and Brown, 1974).

Goats and sheep show intermittent synchronous discharge of sweat from glands. In British saanen goats exposed to 40^0C, the pattern of sweating showed discrete peaks at regular intervals but there was a rapid fall in the amount of sweat produced due to fatigue in sweat glands (Robertshaw, 1968; Jenkinson and Rebertshaw, 1971). Dehydrated goats sweat less than

euhydrated goats with maximum sweat discharge rates of 45 g water/m^2/hour being usual, although the desert adapted Bedouin goat has a sweat rate of 140 g water/m^2/hour (Wilson 1989). Cutaneous evaporation of water is the major route of heat loss in cattle and sheep at high temperatures (McDowell and Weldy, 1967; Robertshaw, 1966). Cattle may lose 23 g/m^2/h at 27°C and up to 50 g/m^2/h under severe heat stress (Roubicek, 1969). There are large differences among species in the importance of sweating with domestic livestock ranked in the descending order of horses, donkeys, cattle, buffaloes, goats, sheep, and swine (McDowell, 1972). The threshold skin temperature for sweating varies among species (McDowell *et al*., 1954). Zebu cattle may secrete up to 0.25 g/m^2/hr when heat stressed (McDowell, 1972), but during cold conditions only 0.~0.02 g/m^2/hr are lost (Murray, 1966). Swine and poultry depend on the respiratory more than cutaneous route for evaporative heat loss. Cutaneous water loss plays a decreasing role in heat loss as temperature rises and heat dissipation occurs predominantly through respiratory water loss (van Kampen, 1974).

Milk production represents a severe drain on the water resources of an animal. The water turnover of lactating camels and sheep in a hot Australian environment has been measured about 44% above that of non-lactating animals (Macfarlane and Howard, 1972), while dairy cattle in the tropics require an extra 3 litres of drinking water for every litre of milk produced (Barrel and Larkin, 1974). However, the moisture content of the milk of arid-adapted ruminants is not very different from that of other livestock (Appendix A_4), probably because the young suckling animal needs water as much as nourishment from milk.

1.5 Factors affecting water intake

There are numerous factors that influence the intake of free water, such as animal species, physiological condition of the animal, level of dry matter intake, physical form of the diet, water availability, quality of water, temperature of the water offered, and ambient temperature (McGregor, 2004).

1.5.1 Differences among species

The amount of water required varies between species of livestock. Aganga (1992) reported that water intake differed significantly between goats and sheep, as well as among the various breeds. McGregor (1986) noted that the water intake of the Angora goats was 50% higher than intake of adult Merino sheep or (Angora goats: 104 ± 4 ml/kg0.82 /day; Merino sheep: 70 ± 3 ml/kg0.82 /day). Ferreira *et al*. (2002) measured the water intake of castrated Boer goat kids (26 kg) and castrated Mutton Merino lambs (32 kg) the Boer goats had a lower water intake per kg of feed intake and per kg of live weight gain than the sheep.

Zebu cattle may have a lower intake of water than European breeds (Ragsdale *et al*., 1950; Winchester and Morris, 1956; Johnson *et al*., 1958;

Colditz and Kellaway, 1972), but there is supposition over whether observed values are directly attributable to genotype due to sampling variance, differences in body size, or level of dry matter intake. When data from these experiments are adjusted to a constant body size and dry matter intake, species differences become negligible. The daily drinking water requirements for non-lactating livestock under African ranching conditions are presented in Appendix (A_2).

1.5.2 Physiological state

Generally the older species drink more water than young ones (Aganga, 1992). The older species were bigger in body size and, consequently, they required more water for proper digestion and utilization of the feed they consumed. With regard to gender, female goats drank more free water than male goats (Aganga, 1992). Maintenance water intake is 107g/kg $^{0.75}$ for a dry and non-pregnant goat, 140 g/kg $^{0.75}$ at mid-pregnancy and 165 g/kg $^{0.75}$ at mid-lactation (Giger-Reverdin and Gihad, 1991). Mean daily water intake was 46 ml/kg in lactating and 36 ml/kg in non-lactating black Moroccan goats (Hossaini-Hilali, 1994). Studies on dehydrated Swedish domestic goats (*Capra hircus*), Olsson *et al.* (1996) indicated that pregnant goats drank 3.5 litres of water, lactating goats drank 6.3 litres, and nonpregnant, nonlactating goats drank only 2.6 litres.

Observations of water intake of ewes under various physiological states showed that lactating ewes drank more water than pregnant and nonpregnant ewes. Water intake of the pregnant ewes was slightly higher than that of non pregnant ewes, but it was significantly lower than that of the

lactating ewes (Aganga, 1992). Ewes carrying twins consume over twice the amount of water consumed by nonpregnant ewes and those carrying single lambs, and 138% above nonpregnant ewes. When corrected for water content of milk, lactating ewes consumed 100 to 164% more water than dry ewes (Forbes, 1968).

1.5.3 Frequency of watering

Water intake of animals will depend upon availability. Abdelatif and Ahmed (1994) reported that water intake for Sudanese desert sheep decreased with increasing the watering interval from 24 to 72h. When goats on grazing have water offered either once every 72, 48, 24 h or *ad libitum* water intake decreased with increasing water interval (Adogla-Bessa *et al*., 2000). Under extensive grazing systems in dry tropical areas, water intake of sheep or cattle will decline as distance to water sources increases. Water intake of sheep declined significantly, about 7.85g /Kg, when distance between feed and water increased from 2.4 to 5.6 Km (Daws and Squires, 1974).

1.5.4 Ambient temperature

Numerous experiments have shown significant positive correlations between water intake and ambient temperature. Olsson and Hydbring (1996) reported that goats reduced their water consumption when the ambient temperature was declined from 40°C to 19°C. For both Angora goats and Merino sheep, water intakes on the hottest days (33 °C) were double the average when the mean temperature averaged 25°C (McGregor, 1986). The relation of drinking water intake to ambient temperature for sheep appears to

parallel that for cattle. From O to 15°C the water intake of growing and fattening sheep is 2.0 kg/kg DM consumed, increased to 2.5 kg at 15~20°C and 3.0 kg above 20°C (ARC, 1965).

1.5.5 Temperature of water

The amount of water intake for livestock also depends on the temperature of the water. Olsson and Hydbring (1996) reported that at normal room temperature (18-19°C), goats drank 6.0 litres of warm water (35°C) but only 1.7 litres of cold water (15°C); while during heat stress (39-40°C), they drank 11.5 litres of the warm water but only 2.0 litres of the cold water, while lactating goats drank 6.86 litres of the warm water and 4.54 litres of the cool water within the first hour after 24 h dehydration (Olsson and Carlsson, 1999). Ittner *et al*. (1951) reported that Hereford cattle in hot environment (38°C) reduced their water consumption when the water temperature was decreased from 31 to 18.3°C.

1.5.6 Water quality

Good water quality is essential for successful livestock production. Poor quality water may reduce animal production and impair fertility. The principal factors affecting water quality include salinity, pH, algae growth and presence of toxic elements and compounds.

1.5.6.1 Salinity

All natural waters contain some dissolved salts (Cummings, 2002). Salinity levels are measured directly by total dissolved solids (TDS) and

indirectly by electrical conductivity (EC) (McGregor, 2004). Dissolved salts in water are expressed in parts per million (ppm) or in terms of the EC of the water, measured in millisiemens per metre (mS/m). Maximum advisable levels are shown in Appendix (A_5).

The main factor which determines the suitability of water for animals is the concentration of dissolved salts in the water (Ray, 1989). Many factors influence the concentration of salts that animals can tolerate in their drinking water. Goatcher and Church (1970) reviewed the limited evidence available and suggested that goats have similar or slightly greater tolerances to salt in water compared with sheep. The tolerance of salty drinking water by different livestock species are presented in the Appendix (A_6). Bell (1959) reported on the thresholds for taste discrimination using British dairy goats offered fresh water and another supply of water with various test solutions with different concentrations. The rejection threshold for each solution was set as lowest concentration where no more than 20% for total fluid intake was consumed. The results are presented in the Appendix (A_7). Many workers found that salinity increased the intake of water by animals, (Peirce, 1957, 1965; Wilson, 1965; Assad *et al*., 1997b).

1.5.6.2 Acidity or alkalinity (pH)

Waters with a pH outside of the preferred range may cause non-specific effects related to digestive upset, diarrhoea, poor feed conversion and reduced water and feed intake. In this respect, there are several studies that indicate the benefits of considering acid-base balance in ruminant nutrition

and animal performance and productivity may be relevant and worthy of serious consideration (Riond 2001).

1.5.6.3 Algae growth and bacteria

The greater exposure to bacterial and algal contamination combined with greater water demands by livestock in summer means that a greater effect on productivity would be expected in summer. Direct sunlight (via the strongly bactericidal ultra-violet component) would be expected to reduce the survival of *E. coli* in troughs as in other aquatic systems (Sinton *et al*. 1999, 2002).

1.5.6.4 Toxic elements and compounds

The intake of minerals and other chemical compounds from drinking water is a potential concern for livestock producers. However, it is important to consider the total intake from all dietary sources. High dietary intakes of some minerals can be important as they can either depress the absorption of essential minerals, or prove toxic. For example, the depression of copper uptake in ruminants resulting from high intakes of molybdenum and sulfur together, or from interference by iron are well established, while lead, fluorine and arsenic are well-known poisons. In a more general sense, elevated concentrations of nitrate, sulphate, zinc and total dissolved solids have been implicated in negatively impacting milk production (Beede and Myers, 2000). Safe levels of toxic elements and ions in livestock drinking water are presented in the Appendix (A_8)

1.6 Sodium and chloride

Sodium chloride is essential for life. The tight regulation of the body's sodium and chloride concentrations is so important that multiple mechanisms work in concert to control them. Although scientists agree that a minimal amount of salt is required for survival, the health implications of excess salt intake represent an area of considerable controversy among scientists, clinicians, and public health experts (Taubes, 1998).

1.6.1 Dietary sources of sodium and chloride

1.6.1.1 Concentrates

A survey by the American Feed Industry Association (AFIA) showed that most grain and vegetative foodstuffs (with the exception of sunflower meal) were poor in sodium, although values were not normally distributed (Berger, 1990). Root crops, root by-products and animal products are generally much richer in sodium than cereals, while animal protein sources, such as fish-meal, meat-meal and dried skimmed milk, are higher in sodium than most plant protein sources. Cereal grains generally provide more chloride (Cl^-) than sodium, with maize providing the least and barley the most (0.5 and 1.8 g Cl / Kg DM, respectively). General straws contain three to sixfold more chloride than the grains. Vegetable protein supplements are consistently low in chloride (0.3-0.7 g / Kg DM), and it is possible to compound mixtures with cereals which provide pigs and poultry with insufficient chloride requirements, but inclusion of animal by-products and grass meal would correct any deficit. Ruminants denied access to roughage could possibly receive inadequate dietary chloride intakes (Underwood and Settle, 1999). The results are presented in the Appendix (A_9).

1.6.1.2 Forages

Minson (1990) reported that the distribution of pasture sodium (Na) concentrations was skewed towards low values, with 50% of samples containing less than 1.5 g Na /Kg DM. There are consistent differences among the more widely grazed species, with differences most marked in the richest species (Chiy and Phillips, 1993). There are also major differences among legumes high leaf sodium concentrations, such as white clover, subterranean clover and red clover (Smith and Middleton, 1978b). Decreases in sodium concentration of grasses (but not legumes) as they mature contribute to the reported variability. Pasture sodium concentrations are influenced by the application of potassium (K) and nitrogen (N) fertilizers; N increases pasture sodium in a dose dependent manner, but the concurrent application of K limits the N response, particularly at high application rates (Kemp,1971). Maize silage is the poorest forage source of sodium. Most pastures are appreciably richer in chloride than they are in sodium, with little difference between legumes and grasses or between fresh grasses or between fresh grass and hay. Thomas *et al*. (1952) reported mean values of 0.8 g Na and 4.0 g Cl /Kg DM in leguminous and 1.4 g Na and 5.0 g Cl /Kg DM in grass pasture species.

1.6.1.3 Drinking water

The sources of drinking water in semi arid areas contain high concentrations of salts with NaCl as the main constituent (Gihad *et al*., 1993). Therefore, its provide sodium for mammals in areas where intakes of sodium from feed are low, but it may provide excessive quantities of salt

(and of other minerals) normally present with the salt, such as sulphates and bicarbonates of sodium, calcium and magnesium. Sodium-deprived animal's show a marked preference for salty water (Blair-West *et al*., 1968; Smith and Middelton, 1978a) and they will even consume sodium bicarbonate ($NaHCO_3$), which is usually avoided (Bell, 1995). When the diet provides sufficient sodium, cattle will discriminate against water containing 1.25% (NaCl) in favour of pure water; pygmy goats show a similar preference, while both sheep and normal goats remain indifferent (Goatcher and church, 1970). The extent to which drinking water meets the supplementary sodium needs of livestock will depend on the degree of deficiency, the amount of sodium in water and the volume of water consumed (Underwood and Settle, 1999). It has been calculated that cattle drinking 40 litres /day would obtain their sodium requirements from water containing about 0.5 g NaCl /L (Loosli, 1978).

1.6.2 Metabolism of sodium and chloride

1.6.2.1 Palatability

The presence of salt in a feed can contribute to the palatability of that feed (Grovum and Chapman, 1988), whereas the addition of salt to a feed replete with sodium can lower feed intake (Wilson, 1966; Moseley, 1980), and may be used as a means of restricting the intake of supplementary foods (De Waal *et al*., 1989). However, sodium appetite is relative rather than absolute and can easily by affect by experience.

1.6.2.2 Absorption

Both sodium and chloride are readily absorbed, but each element can influence the absorption of the other (Henry, 1995). Sodium uptake from the gut lumen is achieved by coupling to glucose and amino acid uptake via cotransporters and also by exchange with hydrogen ions (H^+) via an Na-H antiporter, intracellular H^+ being generated by carbonic anhydrase in the enterocytes of the gut mucosa (Harper *et al*., 1997). Absorption of chloride from dietary and endogenous (gastric secretions) sources is achieved by exchange for another anion, bicarbonate ($HCO3^-$), also generated intracellularly by carbonic anhydrase and secreted into the gut lumen.

1.6.2.3 Membrane transport

Sodium and chloride are highly labile in the body. At the cellular level, the continuous exchange of sodium and potassium via ATP dependent Na^+-K^+ pumps provides the basis for glucose and amino acid uptake (by cotransport) maintaining high intracellular K concentrations but requiring about 50% of the cell's maintenance need for energy (Milligan and Summers, 1986). Any production increases Na^+ and K^+ transport and modeling studies suggest that associated contribution to energy expenditure rises from 18 to 23% as lamb growth increases from 90 to 230 g /day, increased metabolite transport (e.g. amino acids) in the gut mucosa being primarily responsible (Gill *et al*., 1989). Sodium transport across membranes is also achieved by a wide variety of complementary mechanisms by an Na-H exchanger, electroneutral Na-K-2Cl cotransporters, Na-Cl and Na-Mg exchangers and by voltage gated Na^+ channels. Chloride transport is almost as complex, with voltage, mechanically (stretch) activated and Ca activated

channels and also Cl^--$HCO3^-$ exchangers contributing to fluxes (Harper *et al*., 1997).

1.6.2.4 Secretion and excretion

Much of the sodium that enters the gastrointestinal tract comes from saliva, particularly in ruminants, which daily secrete about 0.3 L /Kg live weight (LW) containing sodium (150 mmol / L) as the major cation. The rumen can contain 50% of the available body sodium, providing an important reserve (Bell, 1995). However, in potassium rich diets it is displaced by potassium (Suttle and Field, 1967). In sodium deficiency, salivary sodium is replaced on a molar basis by potassium to conserve sodium (Blair-West *et al*., 1963) in an adaptation modulated by aldosterone, a hormone secreted by the adrenal gland. All three elements (sodium, chloride and potassium) are lost via skin secretions, but there are major differences between species. In non ruminants, including the horse, sodium is the major cation in sweat and salt concentrations in sweat can reach 4.5%. Horses, mules and donkeys sweat profusely when exercised, but the high loss of sodium balances the loss of water and provides a defense against hypernatraemia. Sodium concentrations in milk (normally 17 mmol /L in sheep, 27 mmol /L in cattle) decline only slightly during sodium depletion and there are no compensatory changes in milk potassium to compare with those seen in saliva (Morris and Peterson, 1975).

Regulation of sodium status during fluctuations in sodium intake is achieved principally by the control of reabsorption in the proximal tubule of the kidney. Mediation is achieved by active transport and changes in

membrane permeability. Sodium reabsorption in the distal tubule can be impaired by excess potassium but enhanced by aldosterone, so that urinary losses become negligible when sodium intakes are low (Harper *et al*., 1997). Wittenberg *et al.* (1986) found that in dehydrated goats, aldosterone level was increased while the Na excretion was decreased. Chloride is also reabsorbed in the kidney, but by a passive process. Dietary excesses of sodium and chloride are predominantly excreted via the kidney (Underwood *et al*., 1999).

1.6.2.5 Imbalance of sodium and chloride

Because sodium is the primary determinant of extracellular fluid volume, including blood volume, a number of physiological mechanisms that regulate blood volume and blood pressure work by adjusting the body's sodium content (Ganong, 2003); these include the activation of rennin the angiotensin to angiotensin I and Π, which, with vasopressin, regulate aldosterone secretion, extracellular fluid (ECF) volume and blood pressure through appropriate adjustments in thirst and water balance (Bell, 1995; Michell, 1995). Hemsley (1975) reported that water intake by sheep was significantly increased when salt was given in both the food and drinking water in ruminants; the rate of out flow of digesta from the rumen was increased, with adverse consequences for digestibility (Arieli *et al*., 1989), but possible benefits in terms of undegraded protein outflow (Hemsley *et al*., 1975).

1.6.3 Functions of sodium and chloride

Sodium and chloride are the principal ions in extracellular fluid which includes blood plasma. As such, they play critical roles in a number of life-sustaining processes (Taubes, 1998). It is play an important role in maintenance of the osmotic pressure and extracellular fluid volume. Sheng (2000) reported that in the circulatory system, pressure receptors (baroreceptors) sense changes in blood pressure and send excitatory or inhibitory signals to the nervous system and/or endocrine glands to affect sodium regulation by the kidneys. Sodium is essential for the transmission of nerve impulses and plays an important role in the absorption of chloride, amino acids, glucose and water (Jesse, 2004). Chloride, in the form of hydrochloric acid (HCl), is also an important component of gastric juice, which aids the digestion and absorption of many nutrients (Harper *et al*., 1997). Chlorine is found both within the cells and in the body fluids, including the gastric secretions, where it occurs as hydrochloric acid (HCl) and in the form of salts. Respiration is based on 'the chloride shift', whereby the potassium salt of oxyhaemoglobin exchanges oxygen for carbon dioxide via bicarbonate in the tissue and reverses that process in the lung, where reciprocal chloride exchanges maintain the anion balance (Block, 1994).

1.6.4 Sodium and chloride deficiency

1.6.4.1 Occurrence of sodium and chloride deficiency

A critical shortage of sodium is most likely to occur in animals grazing pastures on soils naturally low in sodium, during lactation, in tropical or hot semiarid areas where large losses of water and sodium occur in the sweat, in heavy or intense physical work and through excessive

sweating. When one or more of these conditions apply continuously for long periods and extra salt is not provided, sodium deprivation is inevitable (Underwood and settle, 1999).

While chloride deficiency usually does not occur naturally, Coppock (1986) has questioned the assumption that sodium will always be the more limiting element and has identified diets based on maize as presenting a risk of chloride deficiency. Chloride depletion might also occur in hot climates, since cattle exposed to 40ºC for 7 h /day are estimated to lose slightly more chloride than sodium in sweat, 1 g /day for 200 kg steer and 1.69 g /day for 500 kg cows (ARC, 1980).

1.6.4.2 Clinical signs of sodium and chloride deficiency

The clinical signs of sodium deficiency occur without a significant decline in plasma or milk sodium concentrations (Seynaeve *et al*., 1996) until the animals are in extremis. Urinary sodium declines rapidly to extremely low values and faecal sodium is also reduced (Jones *et al*., 1967; Michell *et al*., 1988), through reabsorption against a concentration gradient in the lower intestine (Bott *et al*., 1964).

The relationship between plasma aldosterone and salivary Na: K ratio is curvilinear, rapid increases in hormone concentrations occurring when Na:K ratio falls below 5.0 in sheep and goats (McSweeney *et al*., 1988).

In growing goats and sheep, sodium deprivation is manifested within a few weeks by inappetance, growth retardation and inefficiency of feed use, due to impairment of protein and energy metabolism, but digestibility is not affected (Underwood and settle, 1999). The first sign of sodium deprivation

in milking cows is a pica or craving for salt, manifested by avid licking of wood or soil and the urine or sweat of other animals. An extreme appetite for salt can occur within 2-3 weeks of deprivation. Excessive consumption of water (polydipsia) and hence high urine output has been reported (Whitlock *et al*., 1975).

Chloride deficiency can result in metabolic alkalosis and hypovolemia (Jesse, 2004). Study on young calves, the chloride deficiency caused anorexia and lethargy after 7 days with mild polydipsia and polyuria, severe eye defects developed after 24- 46 days' depletion, plasma chloride fell from 96 to 31 mmol /L and there was secondary alkalosis with reductions in plasma sodium and potassium (Neathery *et al*., 1981).

1.6.5 Requirements for sodium and chloride

Studies on West African dwarf kids showed an increase in body weight with sodium supplementation of between 0.4 and 0.5% in drinking water (Ogebe *et al*., 1995).The minimum sodium requirements of lambs for satisfactory growth and of lactating ewes for maintenance of body weight and milk production were estimated to be 1.0 g and 0.8 g Na /kg DM, respectively, in feeding trials (Hagsten *et al*., 1975; Morris and Peterson, 1975).

The minimum chloride requirements of sheep have apparently not been studied experimentally, but this element does not present a problem in practical conditions (Underwood and settle, 1999).

1.6.6 Sodium and chloride toxicities

Dietary excesses of osmotically active elements, such as sodium and chloride, can disturb body functions (e.g. induce oedema). Excesses of sodium and chloride are usually concurrent and they can occur under natural circumstances, coming from saline drinking water or ingestion of plants growing on saline soils. Excesses can also arise from accidental or intentional human interventions (Underwood and Settle, 1999).

Jesse (2004) reported that increase the Na concentration in the cerebrospinal fluid causes neurological impairment in the animal. Hungerford (1990) summarized the symptoms of salt poising in goats as rapid breathing, blindness, ataxia, high temperature, abdomal pain, diarrhoea, excessive thirst, weakness, head pressing and death. There is marked congestion of the mucous membrane of the omasum and abomasum. There is also oedema of skeletal muscles and hydropericardium. Reddened stomach and intestine in addition to the symptoms given for the goats were observed on post mortum.

Daily bolus doses of 10.5 g NaCl /kg LW /day given via rumen cannulae to grazing lambs depressed growth within 4 weeks and, after 9 months, reductions of 26% in weight gain and 14% in clean wool yield were recorded (De Waal *et al*., 1989).

Water containing up to 5 g NaCl /L is safe for lactating cattle and up to 7 g/L is safe for non lactating cattle and sheep (Shirley, 1978), but stock can adapt to concentrations considerably higher than these, at least in temperate climates. Where the winters were cool to mild and the pasture lush, sheep tolerated water containing 13 g NaCl /l, but with 20 g NaCl /l , feed consumption and body weight declined and some animals became weak

and emaciated (Peirce, 1957, 1965). Much higher salt intakes are tolerated when added to the diet if pure water is freely available, because the animal can compensate to some degree by increasing its intake of fresh water, thereby increasing the salt excreting capacity of the kidneys, but when the water is rich in salt, the animal is unable to adapt high salt intake (Underwood and settle, 1999).

1.7 Effects of saline water

1.7.1 Thermoregulation

Salinity decreases the animals' efficiency of thermoregulation under hot conditions (Assad and Elsherif, 2002). In sheep salinity decreased the blood volume, plasma volume, and interstitial fluids which play an important role in coping with heat stress by evaporation (Assad and Elsherif, 2002). El Gawad (1997) reported that respiration rate increased in goats drinking saline well water (0.8 %), while rectal temperatures and pulse rate were only slightly affected. Weeth *et al.* (1960) reported that the rectal temperature was lower while heifers consumed 2% salt drinking water, and were unaffected by the 1% NaCl.

1.6.2 Water intake

Abou Hussien *et al.* (1994) reported that increasing water salinity to 1.7% increased total water intake of goats by 59% and that of sheep by 99%. El Gawad (1997) reported that water intake increased in the goats offered

saline well water (0.8 %) for 6 weeks. Peirce (1957, 1965) reported that the intake of water by sheep increased with increasing concentration of NaCl in the drinking water, so that the intake of saline water (1.3% NaCl) was higher than that of rain water. The water intake of sheep is significantly increased when salt (130g NaCl per day) is given in both the food and drinking water (Hemsley, 1975). The voluntary water consumption of sheep is related to sodium intake, such that the ratio of NaCl intake to total water intake is within the range 1.82 to 2.17% NaCl voluntary water intakes increased up to 11.3L/day (Wilson, 1965).

Studies on cattle showed that the animals on 1% salt water drank more than those on tap or 2% salt water (Weeth *et al*, 1960). Consumption of 2% salt water approached that of tap water after the first 10 days; however, consumption of this salt water was always erratic. Often an animal on 2% salt water would stop drinking for several days and then drink over 100 Lb. in a day (Weeth *et al.,* 1960). High saline water significantly increased water intake of camels without any effect on its body fluids (Assad *et al*., 1997b).

Thornton *et al* (1985) reported that changes in sodium concentration and osmolality in lateral ventricle cerebrospinal fluid caused by intracarotid infusion of hypertonic solutions or urea in conscious goats produced significant increase in osmolality and increases in sodium concentration of the cerebrospinal fluid and increased blood osmolality followed by an increase in water intake. The authors concluded that drinking in goats following peripheral administration of hypertonic solutions is probably due to an osmoreceptor mechanism. A cerebrospinal fluid sodium receptor mechanism is unlikely because hypertonic NaCl or urea both increased the

sodium concentration in cerebrospinal fluid, but only the osmotically effective NaCl solution produced significant drinking.

Houpt (2004) indicated that when hypertonic NaCl solution is administered intravenously in sheep, water begin to shift into the plasma and increased osmolality of the extracellular fluid (ECF) would cause cellular dehydration.

Scott and Morton (1976) reported that, in sheep the infusion of hypertonic NaCl by jugular vein or carotid artery increased the concentration of ADH in the plasma and increased the excretion of Na and Cl in urine.

Abou Hussien et *al*. (1994) reported that the mechanism by which goats and sheep control salt load by drinking saline water is different to that of camels. Goats and sheep excreted more urine and increased the filtration rate to reduce the high salt load resulting from their high consumption of saline water. Camels consumed relatively less saline water to reduce salt stress.

1.7.3 Food intake

The concentration of salts in the drinking water may influence food intake in animals. In the study of Abou Husien *et al*. (1994), intake of water with 0.9% TDS reduced the dietary intake of sheep but not goats. Increasing the salt content from 0.95% to 1.7% TDS reduced the dietary intake of both sheep and goats. Peirce (1957, 1963) found that food consumption declined in animals receiving 2.0% NaCl in the drinking water. Wilson (1966) found that food intake of sheep declined at the higher concentrations of NaCl (10-20% in food, 1.5-2.0% in water), While El Gawad (1997) reported that feed

intake increased in the goats offered saline well water about 0.82% total soluble salts (TSS).

Wilson (1965) reported that intake of Atriplex (salt bush) by sheep decreased to less than half when the drinking water was replaced by water containing 0.9 or 1.2% NaCl, so that in sheep being dependent entirely on salt bush, the drinking water should contain not more than 0.6% NaCl (Wilson, 1965). The sheep with a choice of high and low salt rations can partly avoid the stress of saline drinking water or restricted water supply by changing the proportion of each ration eaten (Wilson, 1968). Arnold (1964) found that sheep in sodium deficiency select grass of high sodium content.

In studies on heifers, hay consumption of animals offered 1% salt water was slightly less than those on tap water, and hay consumption of heifers offered 2% salt water was very low (Weeth *et al.*, 1960).

1.7.4 Body weight (BW)

A concentration of 1% sodium chloride in the drinking water had no adverse effects on the BW of sheep, but there was a decline in BW of several animals receiving 2% salt water (NaCl) and affected animals receiving 1.5% salt water (Peirce, 1957, 1963; Wilson, 1966). McGregor (2004) found that Australian domestic goats on seawater of 3.6% of body weight per day for 24 days occurred with 15 to 20% weight loss. El Gawad (1997) studied the responses of 21 to 46 kg does fed tap water (TSS: 0.1%) or saline well water (0.82%) for six weeks. Goats were individually housed in semi-open pens and fed on hay and a concentrate mixture. The BW was not significantly affected. However, studies on West African dwarf kids

showed an increase in body weight with sodium supplementation of between 0.4 and 0.5% in drinking water, with the upper limit of supplementation applicable in the dry season (Ogebe *et al*., 1995).

Studies on heifers showed the growth rate as indicated by body weight was not affected by drinking 1% salt water; heifers on 1% salt water lost slightly more weight than those on tap water after 16 hours period and heifers on 2 % salt water lost more weight during the first 10 days (Weeth *et al*., 1960).

The importance of dietary mineral supplementation on overall production of animals has been studied. Miles and McDowell (1983) reported that mineral supplementation dramatically increased all production parameters. McClvomnt *et al*. (1957) observed a growth response to sodium chloride in sheep given high grain diets containing 0.01 to 0.06% sodium after a long period of undernutrition. Morris and Gartner (1971) showed an unequivocal growth response in cattle to Na supplementation. McDowell *et al*. (1993) reported weight losses in ruminant due to NaCl deficiency resulting from lack of appetite.

1.7.5 Blood compositions

Blood volume, plasma volume, extracellular fluids and interstitial fluids decreased by increasing salinity concentration for ewes (Assad *et al*., 2002). Meintjes and Engelbrecht (2004) found that in German Merino sheep, both plasma sodium and urea concentrations decreased significantly by drinking 0.45% NaCl, although no further change was recorded with the increase in salt loading to 0.9% NaCl, while plasma potassium concentration

increased by drinking 0.45% NaCl, and increased even further with 0.9% NaCl in the drinking water.

Peirce (1957, 1963) and Hemsley *et al.* (1975) reported that 1% NaCl in the drinking water for Merino sheep had no effect on the concentration of Na, K, Ca or Mg in the blood plasma. However, the chloride concentration was significantly higher throughout the experiment in the group which received water containing 2.0% NaCl. In Barki sheep, the plasma glucose level decreased by salinity (13,535 ppm TDS), while camels were not affected (Assad *et al*., 2002).

The effect of drinking saline water on blood constituents for heifers have been investigated by Weeth *et al* (1960) who reported that there was severe hemoconcentration while heifers were drinking 2% salt water. Serum Na was unchanged by drinking 1% salt water, it was increased an average of 14.2% on 2% salt water. Serum K tended to increase significantly in heifers drinking 2% NaCl. Blood urea was decreased when heifers were drinking either 1 or 2% NaCl. This effect was most apparent on 2% salt water (Weeth *et al*., 1960). Weeth and Haverland (1961) reported that in summer, serum Na and K were increased when the drinking water contained 1.2% NaCl, but not in winter when it contained 1.5% NaCl.

1.7.6 Urine volume and composition

Drinking saline water increased the urinary volume and electrolyte excretion in sheep and cattle relative to those drinking fresh water (Potter, 1963; Weeth and Lesperance, 1965; Tomas *et al*., 1972; Meintjes *et al*., 2004). Also drinking saline water increased the GFR for goats (Godwin and

Williams, 1986) and sheep (Meintjes *et al.*, 2004) receiving high concentrations of NaCl compared to others receiving tap water or low concentrations of NaCl.

The increase in urine output of Na and Cl and the decrease in urinary K associated with drinking water of 1.7% TDS was evident in sheep and goats (Abou Husien *et al*., 1994). In Merino ewes the urinary excretion of Ca, Mg, K, P, Na and Cl was increased by saline water (0.8 and 1.3% NaCl) ingestion, while the faecal excretion of Ca, Mg and P was not affected by the inclusion of sodium chloride in the drinking water, but faecal K was decreased and Na and Cl increased (Tomas *et al*, 1973). The concentrations of Na in the urine of the sheep on the higher salt (2% NaCl) in drinking water increased to over 500m.equiv./L However, the addition of 15 and 20% NaCl to the food led to only a small increase in urinary Na above the values with 10% NaCl (Wilson, 1966).

The excretion of urea was higher for goats (Godwin and Williams, 1986) and sheep (Meintjes *et al*, 2004) receiving high concentrations of NaCl compared to others receiving tap water and low concentrations of NaCl. Abou Husien *et al.* (1994) reported that drinking saline water (1.7% TDS) had no effect on the urea concentration of urine of goats, but decreased it in sheep and camels. The authors concluded that the mechanism by which sheep and goats control salt load by drinking saline water is different from that of camels. Sheep and goats excreted more urine and increased the filtration rate to reduce the high salt load resulting from high consumption of saline water, camels consumed relatively less water to reduce salt stress.

1.8 Effects of dehydration

The intake of water is intermittent, while the loss of water is continuous. As a result, the animal is always faced with the problem of slow dehydration (Aganga, 1992). Dehydration in mammals influences thermoregulation, food intake, blood composition as well as urine composition.

1.8.1 Thermoregulation

The stabilizing properties of water which include transportation of metabolites and loss of heat by evaporation tend to maintain a steady internal environment of the body (King, 1983). Disturbances of water balance influence the body heat balance (Macfarlane, 1964). Freudenberger and Hume (1993) reported that the feral goats reduced their faecal, urinary and evaporative water losses when the voluntary drinking water intake was restricted to 57%. While, Ahmed and El Kheir (2004) reported that water restriction (40% from control group) decreased water turnover rate and evaporative losses, with decreased faecal losses.

Studies were contacted on Nubian and Alpine-Toggenberg goats stood for 90 min in a climate chamber at 40 ^{o}C. Dehydrated animals (24 h water restriction) had lower sweat rates and higher rectal temperature than hydrated animals, but respiratory frequency and respiratory evaporation were the same in hydrated and dehydrated animals. When dehydrated goats

were allowed to drink after 60 min of heat exposure, sweating began abruptly within 3 min of the start of drinking in every animal (Baker, 1989). McGregor (2003) reported that on dry pasture, particularly during drought, the moisture content of dry pasture is very low and there was a little shade. Thus goats are more exposed to direct sunlight and must control their body temperature by panting and sweating, particularly on hot days with strong winds.

In Sudan desert sheep, restricted access to water decreased the morning and afternoon values of rectal temperature and respiration rate (Abdelatif and Amed, 1994). Water deprivation also significantly lowered the respiratory rate in Yankasa sheep (Aganga, 1992), while variations in rectal temperature were slight among animals on varying watering intervals (Aganga, 1992). In contrast, respiratory rate, rectal temperature and pulse rate were higher with 72 hr watering interval of Botswana goats (Adogla-Bessa and Aganga, 2000).

The body temperature of camels may vary by 2 to 3 ^{o}C during the course of each 24-hr period; this variation becomes even grater (up to 6 ^{o}C) when the camel is dehydrated (Schmidt-Nielsen *et al*., 1957).

1.8.2 Food intake

Water and food intake are highly correlated (More *et al*., 1983; Silanikove, 1989; Ferreira *et al*., 2002). As dry matter and water intake are linearly related to each other (MacFarlane and Howard, 1972; Silanikove, 1987a), water restriction or dehydration reduces voluntary feed intake in Sudanese desert goats (Ahmed and Amar, 2001; Ahmed and El keir, 2004),

Sudanese desert sheep (Abdelatif and Amed, 1994), cattle (Martine *et al*., 2001), camels (Ben Goumi, *et al*., 1993) and Humans (Engell, 1988). It would seem clear that there are differences between breeds of goats in their ability to resist dehydration based on genetics and adaptation to thermal environment (McGregor, 2004). Silanikove (2000) reported that desert breeds demonstrate greater capability to ameliorate the stressful effects induced by water deprivation, and therefore maintain higher feed intake and productivity than non-desert breeds. Schoen (1968) reported that the east African goats decreased their feed intake by 20% when their *ad libitum* water intake was reduced by 24-39%. Bohra and Ghosh (1978) noted that the dry matter intake by Marwari sheep was restricted by 50%, while the black Bedouin goats reduced their feed intake by 19% when they were deprived of water for 3 days. The Swiss Saanen goats reduced their feed intake by 42% when deprived of water for 3 days (Silanikove, 1985). Khan *et al* (1978) noted that the Bramer goats reduced their food intake by 39.6% when water was deprived for 4 days. In studies on sheep, Singh *et al*., (1976) reported that sheep reduced their food intake by 8.63% when they were deprived from water for 3 days. The medium wool Merino sheep decreased their feed intake by 38.66% when dehydrated for 4 days (Wilson, 1970). On the other hand, Misra and Khub (2002) reported that water deprivation for 48h did not adversely affect feed intake and nutrient digestability in non-producing adult goats under semi-arid condition of India. Hajigeorgiou *et al*. (2000) noted that a mild water restriction did not have any significant effect on the nutrition of Karagouniko sheep. Adogla-Bessa and Aganga (2000)

found that Feed intake per Kg metabolic weight of Botswana goats increased as water intake decreased from *ad libitum* to the 72h watering interval.

Desert goats seem to be the most efficient among ruminants concerning their ability to withstand dehydration (Silanikove, 1994), however food consumption decreased with the increasing of the period of dehydration in Saanen and black Bedouin goats. The Saanen goats reduced their dry matter intake and consequently their water intake much more than the Bedouin goats. The Bedouin goats are capable of maintaining during 3 days of dehydration a level of consumption which is well above their maintenance requirements while the Saanen goats consumed only the amount of feed which is needed to satisfy their maintenance requirements (Silanikove, 1984). Osman and Fadlalla (1974) reported that when water was withheld from the desert sheep of the Sudan, which were fed on different types of crude protein, their food intake was reduced but the magnitude of change was influenced by the feed type.

1.8.3 Body weight

Most animals reduce their food intake during moderate dehydration and may not eat during severe dehydration. Hence part of the body weight loss of tissue substances is used for energy metabolism because animals reduce their feed intake (Houpt, 2004).

Water deprivation caused a marked decrease in body weight in Sudanese desert goats (Ahmed and Amar, 2001; Ahmed and Al keir, 2004), Tswana goats (Adogla-Bessa and Aganga 2000), sheep (Abdelatif and Ahmed, 1994), cattle (Martine *et al*., 2001) and camels (Ben Goumi, *et al.,*

1993). The decrease in body weight is observed during the dry season, (Umunna *et al*., 1981) reported that during the rainy season, all animals gained weight in spite of the watering intervals imposed on them. Ahmed and Al kheir (2004) reported that the acute effect of water restriction on body weight loss was recorded during the dry summer. Abku and Moruppa (1983) reported that a gradual loss in body weight of goats in the Sahel region occurs during dry season, this loss was equivalent to 18% of their body weight. During complete water deprivation for 5 days, desert goats lost 11.8% of their body weight and when their water requirements were restricted to 50% the loss in body weight was equivalent to 4.1% (Ali *et al*., 1982). Kerstin (2005) reported that during water deprivation, lactating animals become dehydrated more rapidly than nonlactating animals. Hossaini-Hilali (1994) reported that 48 h of water deprivation caused a body weight loss of 9% and 6% in lactating and non-lactating goats, respectively.

1.8.4 Blood Compositions

The restriction of drinking water or dehydration may influence the volume and composition of blood in animals. Reducing the water intake to 25% appears to reduce the blood volume, while a reduction in water intake to 75% of their normal requirements had no influence on blood volume in Marwari sheep (Purohoit *et al*., 1972). Reducing in blood volume was increased variably the concentration of many blood constituents. Abdelatif (1978) reported that the changes which occur in the blood constituents are modulated mainly by haemoconcentration following dehydration in Nubian goats and desert sheep. Increases in packed cell volume (PCV) and haemoglobin concentration (Hb) during water deprivation were reported by

many workers for goats (Abdelatif, 1978; Musa, 1978; Ghosh, 1983; Adogla-Bessa and Aganga, 2000).

Purohit *et al*. (1972) reported that in Marwari sheep the PCV increased by 13% when water was restricted to 50%. When they were totally deprived from water for 3 days, their PCV increased by 32%. Also water restriction increased the PCV in Yankasa ewes (Aganga *et al*., 1988) and Sudanese desert sheep (Abdelatif and Ahmed, 1994).

When water was deprived from the Barmer goats for 4 days, the total plasma protein concentration increased by 4.4%, the plasma globulins concentration increased by 8.52% and the plasma albumin increased by 22.49%, the albumin / globulin ratio increased by 31.57% (Khan, 1978). In Moroccan goats, plasma total protein and Na concentrations were increased during dehydration (Hossaini-Hilali *et al*., 1994)

The urea blood level was increased by water restriction (Mousa, 1978; Bohra and Ghosh, 1983; Aganga *et al*., 1988; Abdelteif and Ahmed, 1994). Maloiy (1971) reported that the urea concentration decreased when sheep were fed on low protein diet and restricted their water intake. Little *et al*. (1976) reported that restriction of water intake in cattle was associated with linear increase in the blood urea concentration.

Water deprivation for 29.5 h increased plasma osmolality and vasopressin concentration in goats (Olsson and Dahlborn, 1989; Hossaini-Hilali *et al*., 1994).

In desert sheep, water restriction increased the plasma osmolality and free fatty acids, and decreased glucose concentration (Abdelteif and Ahmed,

1994). In dairy cows blood urea concentrations as well as plasma sodium and PCV were increased by 50% water restriction (Martine *et al*., 2001). In studies on dromedary camels, dehydration decreased plasma volume and a concomitant rise in plasma Na concentration, plasma arginine-vasopressin and plasma renin activity, without significantly changed plasma concentrations of aldosterone and atrial natriuretic peptide (Ben Goumi, *et al.*, 1993).

1.8.5 Urine compositions

During dehydration, different breeds of goats were shown to conserve body water by reducing urine volume such as East African goats (Schoen 1968), Turkana goats from Kenya (Maloiy and Taylor 1971), feral goats (Freudenberger and Hume, 1993), Tswana goats (Adogla-Bessa and Aganga, 2000).

The restriction of drinking water or dehydration may influence the glomerular filtration rate (GFR) and effective renal plasma flow (ERPF) Wittenberg (1986) reported that in goats that were dehydrated to a loss of about 30% of their initial body weight, urine flow dropped to 24% of the value recorded in the hydrated animals and GFR and ERPF dropped to half level recorded in the hydrated phase.

The hormones aldosterone and the anti diuretic hormone (ADH) may influence the volume of urine excreted. William (2004) reported that tubular

fluid osmolality continues to be lowered in the distal convoluted tubule and the connecting tubule because of active transport of Na and continued tubular impermeability for water. Aldosterone stimulates Na reabsorption and ADH increases the permeability for water, thus the net effect of ADH activity is to return water from the tubular fluid to the extracellular fluid (ECF) and thus lower the effective osmotic pressure in the ECF, thereby minimizing the effects of water loss. Wittenberg *et al* (1986) found that in dehydrated goats, aldosterone level and plasma renin activity increased. Olsson *et al*. (1989) reported that water deprivation increased vasopressin concentration in lactating goats.

Urine output, faecal output/ Kg metabolic weight and faecal moisture content decreased with increased length of water deprivation in Tswana goats (Adogla-Bessa and Aganga, 2000). Ali *et al* (1982) found that after 8 days of 50% water restriction, goats, desert sheep and camels reduced their faecal moisture by 75%, 75% and 60%, respectively.

The urinary K / Na ratio increased considerably while urinary Na concentration decreased after the 4 days of water deprivation in Barmer goats (Khan *et al*., 1978). Na and K excretion decreased in the water deprived goats (Wittenberg *et al*., 1986).

In studies in camels, Ben Goumi *et al.* (1993) reported that dehydration was associated with increased urine osmolality, reduced urine production and increased Na excretion.

1.9 Objectives

The present studies were designed to investigate the following relation ships in Nubian goats

1- The effects of saline water on thermoregulation and blood and urine composition.

2- The effects of saline water drinking and the state of body hydration on thermoregulation and blood composition.

3- The effects of seasonal changes in the thermal environment on the thermoregulation, blood and urine compositions.

CHAPTER TWO

MATERIALS AND METHODS

2.1 Experimental animals

A total number of 8 healthy non-pregnant Nubian goats were used in the studies. The goats were 2½ – 3 years old with an average body weight of 25 kg at the beginning of the studies. The animals were obtained from the local market at western Umdurman.

The animals were kept for an adaptation period of about one month. During this period they were given prophylactic antimicrobial treatment (Sulphadiamadin pyrimidine, Richter-pharma, Austria, 1ml/10kg BW) and a full dose of multivitamins (Avitone, Star laboratories (PVT.) LTD. Pakistan: 2g/10 kg BW) in drinking water to provide a common health status among the goats. The goats were dewormed with anthelmintic (Albendazol, Pharmavet, 7.5 mg/kg, 1 ml/13 kg BW) and washed by hand with Amitix (Amitraz 12.5%- Richter Pharma-Australia: 2 ml/Litre water), against ecto-parasites.

All the animals were subjected to clinical examination before the beginning and during the course of study. The animals were ear tagged for identification.

2.2 Housing

The studies were conducted at the Faculty of Veterinary Medicine, University of Khartoum at shambat (latitude 15° 40´ North, longitude 32° 32´ East and 380 m above mean sea level).

The animals were housed in a shaded building (16×14×10 m.). The wall of the building was made of bricks, the eastern side was 10 meters high and the three other sides were about 4 meters high. The floor was made of concrete and the roof was made of corrugated zinc. Inside the building 12 identical pens were constructed of iron (1.5×1×1.5 m.). There was adequate ventilation in the pens and sufficient protection from rains and solar radiation.

2.3 Feeding

The animals were fed on a ration of lucerne hay (*Medicago Sativa*) chopped by grinding machine. Each animal was offered daily 1.5 kg of food at 9:00 am. Food residues were removed and weighed daily. The daily feed intake was recorded every morning at 9:00 am before fresh food was offered. The daily food intake for each animal was obtained by subtracting the feed residues from feed offered.

2.4 Water intake

The drinking water consisted of tap-water or tap water to which sufficient sodium chloride (NaCl) had been added to give concentrations of 0.8, 1.2, 1.6 and 2.0% sodium chloride. The water was offered daily at 9:30 am in individual plastic buckets. The daily water intake of each animal was

measured to the nearest 5 ml by a graduated measuring cylinder every morning at 9:30 am. Evaporative water loss was determined by placing 4 litres of water in an identical bucket; the water intake of each animal was adjusted for evaporative loss.

2.5 Climatic measurements

The daily maximum, minimum and mean ambient temperature (Ta) and relative humidity (RH) readings were obtained from Shambat Meteorological unit located about 500 meters from the experimental site.

2.6 Rectal temperature (Tr)

The measurements of Tr of experimental animals were made to the nearest 0.1℃ using an electronic digital thermometer (ARTSANA- Grandate co-Italy), the animals were handled gently and the thermometer prope was carefully inserted about 5 cm into the rectum. The reading was obtained when stabilized after about 2 min.

2.7 Respiration rate (RR)

The respiration rate (RR) (breaths / min) was measured visually by counting the flank movements with the aid of a stop watch. The values were taken for one minute of regular breathing with the animal standing quietly.

2.8 Body weight (BW)

During the experimental period, the animals were weighed in the morning, to the nearest 0.5 kg using a spring balance (SALTER- England).

2.9 Blood analysis

2.9.1 Collection of blood samples

The area in the jugular farrow was closely clipped and wiped clean with alcohol (70% ethanol). The blood samples were drawn from the jugular vein using 5 ml plastic disposable syringes. A sample of 6 ml of blood was collected, and immediately 1 ml was transferred to a capped test tube containing the anticoagulant sodium ethylene diamine tetra acetate (Na_2-EDTA). Sodium fluoride was added to inhibit the enzymatic reaction that influences glucose concentration (Kelly, 1984). Then the rest of the sample was centrifuged at 3000 r.p.m. for 15 min. the haemolysis-free plasma separated was used for glucose determination. 1 ml of blood was also transferred to another test tube containing EDTA; the sample was used for hematological studies. The rest of the blood sample was allowed to stay for 4–5 hours at room temperature and then centrifuged (Gallenkamp Junior centrifuge) at 300 r.p.m. for 15 min. Haemolysis-free serum was separated and transferred to clean plastic vials and immediately frozen at –20°C for subsequent analysis.

2.9.2 Erythrocytic indices

2.9.2.1 Haemoglobin concentration (Hb)

Hb concentration was determined by the cyanomethaemoglobin method as described by Van Kampen and Zijlstra (1961).

Principle

Ferrous ions of Hb are oxidized to the ferric state by potassium ferricyanide to form methaemoglobin, which reacts with cyanide to form cyanomethaemoglobin that can be measured colorimetrically.

Reagents

Cyanide reagent (Drabkin's solution)

This was prepared by dissolving 0.2g of potassium cyanide, 0.05g of ferricyanide and 0.14g of potassium hydrogen diorthophosphate in one litre of distilled water.

Standard Hb solution

One ml of human Hb standard (Biosystem-Spain), with a concentration of 11.5 g /dl was used as standard.

Procedure

Clean dry test tubes were prepared for sample and standard. To each tube, 4ml of cyanide reagent was added. Then 0.2 ml of blood sample and Hb standard solution were added to the sample and standard test tubes, respectively. The tubes were allowed to stand for 15 min, and then the optical density (O.D.) was read at 540 nm in a colorimeter (Corning -250) using cyanide reagent as blank.

Calculation

$$\text{Blood Hb concentration (g/dl)} = \frac{\text{O.D Test}}{\text{O.D standard}} \times 11.5$$

2.9.2.2 Packed cell volume (PCV)

The PCV of erythrocytes as percentage of whole blood was measured using a microhaematocrit centrifuge (Hawksley, London). Plain capillary tubes were filled with blood to approximately ¾ and one end was closed with cristaseal. Then the tubes were centrifuged at 11000 r.p.m. for 5 min. The PCV was measured as percentage of whole blood using the reader.

2.10 Plasma and serum metabolites

2.10.1 Plasma glucose level

The Plasma glucose level was determined by the enzymatic colorimetric method using a Kit (Randox Labrotory Ltd-London).

Principle

The plasma glucose concentration is determined by enzymatic oxidation in the presence of glucose oxidase. The hydrogen peroxide formed reacts, under catalysis, with phenol and 4 aminophenazol to form a red-violet dye as indicator.

$$\text{Glucose} + O_2 + H_2O \xrightarrow{\text{Glucose Oxidase}} \text{gluconic acid} + H_2O$$

Reagents

The reagent consists of 0.1 mmol/L of phosphate buffer (pH: 7.0), 1.1 mmol of phenol, 0.77 mmol of 4-aminophenazone, 1.5 IU/L glucose

oxidase and 1.5 IU/L peroxidase. The standard was prepared by dissolving 100 mg of glucose in 100 ml of distilled water.

Procedure

For the test, 0.01 ml of the plasma was added to 1 ml of glucose reagent. For the standard, 0.01 ml of standard was added to 1 ml of the reagent.

The contents of the tubes were mixed and allowed to stand for 30 min. at room temperature. Then the optical densities (O.D.) of the sample and standard were read at 540 nm using a colorimeter (Corning-250).

Calculation

$$\text{Plasma glucose concentration (mg/dl)} = \frac{\text{O.D. Sample}}{\text{O.D. Standard}} \times 100$$

2.10.2 Serum total protein

Serum total protein concentration was determined by the Biuret reagent method as described by King and Wooton (1965).

Principle

Protein contains a large number of peptides. When a solution of protein is treated with Cu ions in a moderately alkaline pH, a coloured chelate complex is formed between the Cu^{+2} and peptide bonds to give violet coloured complex. Amino acids and dipeptides cannot give a reaction. In the Biuret reaction, one copper atom complexes with 4 molecules of Biuret, the

linkage being to the central nitrogen atom, the shade of colour being different with different proteins.

Reagent

Biuret reagent (stock reagent)

9.0 g of solution potassium tartrate were dissolved in 400 ml of 0.2 N NaOH. 3 g of copper sulphate ($CuSO_4$.$7H_2O$) and 5g of potassium iodide were added and the volume was made up to 1 litre with 0.2 N NaOH.

Colour reagent

From the stock reagent, the working reagent was prepared by diluting 50 ml of stock reagent to 250 ml with 0.2 N NaOH solution.

Procedure

The blank was prepared by adding 0.2 ml of distilled water to 3 ml of Biuret reagent. The test solution was prepared by mixing 0.2 ml of serum with 3 ml of Biuret reagent, while the standard consisted of 0.2 ml of standard (6 g bovine albumin/100 ml distilled water) and 3 ml of Biuret reagent. Each of the three tubes: blank, test and standard were thoroughly mixed and allowed to stand for 30 min. at room temperature.

The optical density (O.D) of the solutions was read at 540 nm using a spectrophotometer (JENWAY-6150 Ultraviolet-USA).

Calculation

$$\text{Serum total protein concentration (g/dl)} = \frac{\text{O.D. Sample}}{\text{O.D. Standard}} \times 6$$

2.10.3 Serum albumin

Serum albumin concentration was determined by the colorimetric method of Barathalomew and Delaney (1966).

Principle

This method depends on dye binding. Bromo-cresol green (BCG) is the best binding reagent that gives green colour with albumin at low pH (3.8 – 5.0).

Reagents

0.174 g of BCG was dissolved in 25 ml of 0.1 N NaOH and the volume was made up to 250 ml with distilled water. 6 ml of BCG were added to 17.3 ml of 29.4% molar citric acid. The volume was made up to 1 litre with distilled water, and the pH was adjusted to 3.8. This constitutes the buffer reagent.

Procedure

4 ml of the colour reagent were used as a blank to adjust zero point . For the standard, 0.2 ml of standard solution (4 g bovine albumin/100 ml distilled water) was added to 4 ml of colour reagent. For the test, 0.2 ml test sample (serum) was added to 4 ml of colour reagent.

All the tubes were mixed well and the optical density (O.D.) was red at 640 nm using a spectrophotometer (JENWAY-6150 Ultraviolet-USA).

Calculation

$$\text{Serum albumin concentration (g/dl)} = \frac{\text{O.D. sample}}{\text{O. D. standard}} \times 4$$

2.10.4 Serum urea

Serum urea concentration was determined by the colorimetric method of Evans (1968).

Principle

The method is based on a modification of urea reaction with diacetyl monoxime (DAM) at high temperature in an acid medium in the presence of thiosemicarbazide (TSC).

$$\text{Urea + DAM} \xrightarrow{\text{Heating (100 }^{o}\text{C)}} \text{DAM – Urea compound (red colour)}$$

Reagents

Stock reagent of DAM

DAM stock solution was prepared by dissolving 2.5 g of DAM in 100 ml of distilled water.

Stock reagent of TSC

TSC stock solution was prepared by dissolving 0.25 g of TSC in 100 ml of distilled water.

Acid reagent

The acid reagent was prepared by adding to 1 litre of distilled water, 80 ml of concentrated sulphuric acid (H_2SO_4), 10 ml of 80 % phosphoric acid (H_3PO_4) and 10 ml of 5% ferric chloride (anhydrous).

Working reagent of DAM /TSC

DAM/TSC working reagent was prepared by adding 100 ml of stock DAM to 10 ml of stock TSC and the volume was made up to 100 ml by distilled water.

Colour reagent

25 ml of acid reagent was added to 5 ml of DAM- TSC working reagent.

Standard stock

Standard stock solution was prepared by dissolving 10 ml of urea in 100 ml of distilled water. The working standard solution was prepared from stock standard solution by adding 10 ml of stock standard to 50 ml of 10% trichloroacetic acid (TCA) and then volume was made up to 100 ml by distilled water.

TCA (5%)

50 ml of 10% TCA was placed in a volumetric flask and the volume was made up to 100 ml with distilled water.

Procedure

Protein precipitation

To 0.8 ml of water in a centrifuge tube, 2 ml of serum sample was added and followed by 1 ml of 10% TCA. The solution was mixed well and centrifuged at 3000 r.p.m. for 5 min. Then the supernatant was transferred to a new test tube.

The samples, standard and blank were prepared by placing 0.5 ml of supernatant, working standard and 5% TCA separately in 3 test tubes respectively. To each tube, 5 ml of colour reagent were added; then mixed well and placed in boiling for 5 min. After cooling, the optical density (O.D.) of the solution was read at 520 nm using a spectrophotometer (JENWAY-6150 Ultraviolet-USA).

Calculation

$$\text{Urea concentration (mg / dl)} = \frac{\text{O.D. Sample}}{\text{O.D. Standard}} \times 10$$

2.11 Serum inorganic constituents

2.11.1 Sodium (Na)

The concentration of Na in serum was determined by flame photometer technique as described by Wooton (1974).

Reagents

A stock solution of NaCl (1000 mEq/L) was prepared by dissolving 58.56 g of dry (Analar) NaCl in one litre of distilled water. A working standard solution was prepared by dilution of the stock standard with distilled and deionized water 1:50. The calibration curve for sodium was constructed using dilutions of the standard solution to give 120, 130, 140 and 150 and 160 Na mEq/l concentration of Na solution.

Procedure

A volume of 0.1 ml of serum was diluted with 9.9 ml of distilled and deionized water in a test tube. The zero reading was adjusted by distilled and deionized water and the high standard adjusted to the upper setting of 100 using the working standard solution. Then the standard and sample were measured using flame photometer. Serum Na concentration was read from the standard curve (Appendix A_{10}).

2.11.2 Potassium (K)

The concentration of K in serum was determined by flame photometer technique as described by wooton (1974).

Reagent

A stock solution of K (100 mEq/L) was prepared by dissolving 7.46 g of dry (Analar) KCl in one litre of distilled water. A working standard solution was prepared by adding the stock standard with distilled and deionized water 1:50. The calibration curve for K was constructed using dilutions of the standard solution to give 2, 4, 6 and 8 K mEq/L concentration of potassium solution.

Procedure

A volume of 0.1 ml of serum was diluted with 9.9 ml of distilled and deionized water in a test tube. The zero reading was adjusted by distilled and deionized water and the high standard adjusted to the upper setting of 100 using the standard work solution. Then the standard and sample were measured using the flame photometer. Serum K concentration was read from the standard curve (Appendix A_{11}).

2.11.3 Magnesium (Mg)

The concentration of Mg in serum was determined by colorimetric method using titan yellow reagent as described by Neill and Neely (1956).

Principle

The method is based on the reaction of titan yellow with Mg ions to give a red colour.

Reagents

Titan yellow stock solution

For stock solution, 0.5 g of titan yellow was dissolved in 100 ml of distilled water. A working solution was prepared from the stock solution by diluting of 2 ml of stock solution in 100 ml of distilled water.

Polyrinyl alcohol solution

One g of polyrinyl alcohol was dissolved in 400 ml of distilled water using gentle heading, then cooling and the volume was made up to 1 litre with distilled water.

Sodium hydroxide, Na OH (7.5%)

15 g of Na OH was dissolved in 200 ml of distilled water.

Standard stock solution

8.358 g of analytical MgCl (Analar) was dissolved in 1 litre of distilled water. A working solution was prepared by diluting 1 ml of standard stock solution with 100 ml of distilled water.

Procedure

Tubes for sample and standard were prepared by placing 0.2 ml of serum and working standard in 2 test tubes, respectively. 3 ml of distilled water were placed in a test tube used as blank.

To all tubes, 0.5 ml of polyrinyl alcohol, 0.5 ml of working titan yellow and 1 ml of 7 % Na OH solution were added, and the tubes were allowed to stand for 5 min., then the optical densities (O.D.) were read at 540 nm using a spectrophotometer (JENWAY- 6150 Ultraviolet- USA).

Calculation

$$\text{Mg concentration (ml/dl)} = \frac{\text{O.D sample}}{\text{O.D standard}} \times 2.5$$

2.12 Urine analysis

2.12.1 Collection of urine samples

The urine samples were taken using a catheter tube (Romed, Holand: 8mm. in diameter) which was cleaned by antiseptic solution (Chloroxylenol 70%) and lubricated by petroleum jell. The vagina of the goat was cleaned by antiseptic solution (Chloroxylenol 20%) and opened by vagina scope, then the catheter was inserted through the urethra into the bladder. A sample of 20 ml of urine was collected into a clean bottle and 3-5 drops of toluene and sulphuric acid (0.05%) were added to each bottle as preservatives. Samples were kept frozen at –20°C for subsequent analysis.

The analyses of urine urea, Na, K and Mg were performed by the techniques used for serum analysis. However, the urine samples were diluted by adding 1 ml of urine sample to 99 ml of distilled water.

2.13 General experimental plan

The general experimental plan is outlined in Table 1. The details of the experimental procedure are presented in specific chapters. Two experiments have been designed and conducted to investigate the effects of salinity, dehydration and rehydration on the physiological responses of Nubian goats. In experiment 1, the effect of gradual increase in the

concentration of NaCl in drinking water was evaluated in female goats during summer and winter. In experiment 2, the combined effect of saline load and water deprivation was investigated in Nubian goats in wet summer.

2.14 Statistical analysis

The experimental data obtained was subjected to standard methods of statistical analysis. The statistical analysis was performed using Statistical Analysis System (SAS, 1988). The analysis of variance (ANOVA test) was used to evaluate the data in these experiments. In experiment 1 the analysis of variance was used to evaluate the effect of increasing the concentration of NaCl in drinking water on thermoregulation and blood and urine composition during summer and winter. In experiment 2, the statistical analysis was performed to evaluate the combined effect of salinity of drinking water, dehydration and rehydration on thermoregulation and blood composition in goats.

able 1: General experimental plan.

Experiment	Treatment	Thermal environment	Experimental period (days)	Number of goats	Experimental period (days)	Parameters
(1) Effects of season, salinity of drinking water on thermoregulation, blood and urine composition	Salinity of drinking water (NaCl: 0.8-2.0%)	Summer and winter	40	8	40	Food intake, water intake, body weight (BW.), rectal temperature (Tr), respiration rate (RR), blood and urine composition.
(2) Effects of salinity of drinking water, dehydration and rehydration on thermoregulation and blood composition	Salinity of drinking water (NaCl: 1.2%) + dehydration + rehydration	Wet summer	16			

CHAPTER THREE

THE EFFECT OF SALINITY OF DRINKING WATER AND THERMAL ENVIRONMENT ON THERMOREGULATION AND BLOOD AND URINE COMPOSITION IN NUBIAN GOATS

3.1 Introduction

In arid areas, the sources of drinking water contain high concentrations of salts with NaCl as the main constituent (Gihad *et al*., 1993). Therefore, these sources provide sodium for mammals in areas where the intakes of sodium from feed are low, but it may provide excessive quantities of salt and other minerals (Underwood and settle, 1999). Salt poising in goats causes rapid breathing, blindness, ataxia, high temperature, abdomal pain, diarrhoea, excessive thirst, weakness, head pressing and death (Hungerford, 1990).

Drinking saline water may affect the thermoregulation of animals. Assad and Elsherif (2002) reported that salinity decreases the animals' efficiency of thermoregulation under hot conditions. Dmi'el (1986) reported that the heat defense mechanisms in goats are related to their water balance and the mode of heat stress. The excretion of additional absorbed Na is usually associated with loss of large amounts of water (Marks and Tobada, 1998).

The concentration of salts in the drinking water may influence water and food intake in animals. Abou Hussien *et al.* (1994) El Gawad (1997) reported that increasing water salinity increased total water intake for goats.

Meintjes *et al*. (2004) reported that in sheep, drinking saline water increased water intake. Abou Husien *et al*. (1994) reported that with high salinity of drinking water, feed intake was decreased in goats and sheep.

Blood volume, plasma volume, extracellular fluids and interstitial fluids decreased by increasing salinity concentration (Assad *et al*., 2002). This decrease was associated with haemoconcentration (El Hassenein *et al*., 1996). Meintjes *et al*. (2004) reported that in German Merino sheep both plasma Na and urea concentrations were decreased significantly by drinking saline water, while plasma K concentration was increased. The authors indicated that increased urine flow rate lead to increase in renal urea excretion and a decrease in blood urea concentrations.

Mineral supplementation dramatically increased all production parameters (Miles and McDowell, 1983). The wool growth rates of sheep fed on a high protein diet consisting mainly of linseed meal were significantly increased when salt (130g NaCl per day) was given in both food and drinking water (Hemsley, 1975).On the other hand, Solomon *et al*. (1995) showed that water salinity negatively affected milk production in cows; improvement of water quality by desalination increased production of milk and milk constituents. In addition, mineral supplementation was shown to influence the reproductive performance of animals. Ogebe (1995) reported that West African dwarf kids offered sodium supplement via drinking water attained sexual maturity 2 to 3 weeks faster than those receiving tap water.

Animals kept under tropical conditions are also exposed to other stress factors such as heat and cold (Assad, 2002). Seasonal changes in the thermal

environment affect the physiological responses of animals, and there are changes in thermoregulation and blood composition related to climatic stress and thermal acclimatization (Muti and Mullick, 1961). Aganga (2000) reported that feed intake of Botswana goats was higher in winter than summer, but animals drank more water in summer than winter, thus the daily weight gain was higher in winter than summer. In cattle, summer heat load causes a reduction in feed and energy intakes (Young and Hall, 1993), and consequently a decline in productivity (Blackshaw and Blackshaw, 1994). This was shown to be associated with decreased growth rate (Turner, 1984), lower milk production (Wolfenson *et al*., 1988), and reduced reproductive performance (Brown, 1974).

The information reported in literature indicates the influence of salinity of drinking water on the general physiological responses of animals. However, little is available regarding the combined effects of salt load and thermal environment of animals (Assad *et al*, 2002). McGregor (2004) reported that the impact of minerals in deep well water on the health and productivity of goats is not known. The effects on health and production of goats by changing the drinking water from surface run off water to saline bore water as goats are grazed in different paddocks have not been documented. Moreover, there are no published reports on the effects of drinking saline water and thermal environment in adult Nubian goats under tropical conditions. The objective of this experiment was to investigate the effects of increase in the salinity of drinking and seasonal changes in thermal environment on physiological responses of Nubian goats.

3.2 Experimental Plan

A total number of 8 female Nubian goats were used in this experiment. The animals were divided into two equal groups of 4 each, control and treated. The control group was offered tap water (the small proportion of NaCl present in tap water was disregarded). Animals in treated groups were offered tap water in which sufficient sodium chloride supplement had been dissolved to give concentration of 0.8, 1.2, 1.6 and 2.0% NaCl during four consecutive periods (P1–P4) of 10 days each. The amount of feed and water consumed were recorded every morning before fresh feed and water were offered. Tr and RR were measured every two days at 8:30 a.m. and 2:30 p.m. The body weights of the goats were measured on day 1 and day 10 during the experimental period at 8:30 a.m. Blood samples were drawn from the jugular vein on days 0, 6 and 10 of each period. Hb, PCV, plasma glucose level and serum total protein, albumin, urea, Na, K, and Mg were determined. Urine samples were collected on days 0, 6, and 10 of each period between 12:00 a.m. and 2:00 p.m. using a catheter and the concentration of Na, K, Mg and urea were determined. This experimental protocol was executed under typical winter and summer thermal environments.

The minimum and maximum ambient temperature (Ta) and the mean relative humidity (RH) were obtained from the Meteorological station located about 800 meters from the experimental site.

3.3 Results

3.3.1 Climatic measurements

The mean minimum and maximum ambient temperature (Ta) and mean relative humidity (RH) for the experimental periods during winter and summer are shown in Table 2. The meteorological data indicate that the mean values of Ta in summer were higher than values of the winter, but the mean value of RH in the winter was above that of the summer. There was a negative correlation between the mean values of Ta and the mean values of RH ($r = -0.23$).

3.3.2 Rectal Temperature (Tr) and Respiratory Rate (RR)

Table 3 shows the results of the effects of salinity of drinking water and season on rectal temperature (Tr) and respiratory rate (RR).

In winter Tr values measured in the morning (8:30a.m) and in the afternoon (2:30 p.m) showed the highest values at P2 for both control and treated groups which did not differ from each other ($p > 0.05$). In summer, the highest values were also recorded at P4 with no different between control and treated group. But for the morning, during P1, P2 and P3, Tr increased significantly ($p < 0.01$) in treated groups compared with the control groups. For the control and treated groups, the values of Tr recorded at 8:30 a.m in summer were higher than the respective values recorded in winter (Fig. 3a).

Table 2. The prevailing climatic conditions during the experimental period in winter and summer.

		Winter				Summer			
		Experimental period				Experimental period			
		P1	P2	P3	P4	P1	P2	P3	P4
Ta(ºC)	Min	9.97	16.54	13.72	15.59	18.99	22.81	25.3	26.12
	Max	27.05	33.6	32.59	32.05	39.34	39.11	40.7	43.46
	Mean	18.51	25.07	23.16	23.82	29.17	30.96	33.00	34.79
RH%	Mean	26.2	32.5	19.3	15.5	15	14.4	13.9	28.3

In winter, RR values (Fig. 4) recorded in the morning and in the afternoon showed the highest values at P2 for control and treated groups, Also, the values of Tr recorded at 2:30 p.m in summer were higher than the respective values recorded in winter (Fig. 3b). There was a positive correlation ($r = + 0.84$) between the mean values of Tr and ambient temperature (Ta) as shown in Fig. 5. which did not differ from each other. In summer, RR of treated groups in the morning were higher significantly ($p<0.05$) than control groups only in P1. The values of RR measured at 8:30 a.m. for control and treated groups were higher in summer than in winter (Fig. 4a). Also, the values measured at 2:30 p.m. for control and treated groups were higher in summer than in winter (Fig. 4b). The increase in RR in relation to the Ta is shown in Fig. 6. There was a positive correlation ($r = + 0.93$) between the mean values of RR and Ta.

In both seasons, the values of Tr and RR recorded at 2:30 p.m were significantly higher ($p< 0.001$) than the respective values recorded at 8:30a.m.

Table 3. The effects of salinity of drinking water on rectal temperature (Tr) and respiration rate (RR) of Nubian goats at 8:30 a.m and 2:30 p.m during winter and summer. (n = 40, mean ± SE.M.)

Parameter	Water type	Winter					Summer				
		Experimental period				S.E.	Experimental period				S.E.
		P1	P2	P3	P4		P1	P2	P3	P4	
Tr(ºC) : 8:30 a.m.	Tap(Ctrl)	37.32^{b1}	38.16^{a1}	$37.8a^{b1}$	37.54^{b1}	0.10^{*}	37.98^{c2}	38.11^{bc2}	38.22^{b2}	38.51^{a1}	0.04^{**}
	Saline(Treat)	37.88^{bc1}	38.31^{a1}	37.99^{b1}	37.67^{c1}	0.05^{**}	38.26^{c1}	38.34^{bc1}	38.46^{b1}	38.65^{a1}	0.04^{**}
S.E.		0.17	0.04	0.07	0.09		2.29**	0.04*	0.05*	0.04	
Tr(ºC) : 2:30 p.m.	Tap(Ctrl)	38.64^{b1}	38.9^{a1}	38.7^{b1}	38.65^{b1}	0.03*	38.7^{b1}	38.76^{b1}	38.82^{b1}	38.96^{a1}	0.02^{**}
	Saline(Treat)	38.57^{b1}	38.81^{a1}	38.63^{ab1}	38.49^{b1}	0.04*	38.69^{c2}	$38.79b^{c1}$	38.95^{ab1}	39.01^{a1}	0.03^{*}
S.E.		0.05	0.04	0.05	0.04		0.06**	0.03	0.04	0.03	
RR(min^{-1}):8:30 a.m.	Tap(Ctrl)	20.7^{b1}	23^{a1}	20.4^{b1}	20.6^{b1}	0.26^{**}	28.1^{c2}	28.6^{c1}	33.7^{b1}	41.0^{a1}	0.96^{**}
	Saline(Treat)	20.4^{b1}	22.8^{a1}	20.2^{b1}	19.8^{b1}	0.23^{**}	29.8^{b1}	29.8^{b1}	37.0^{a1}	40.0^{a1}	0.94^{**}
S.E.		0.23	0.43	0.17	0.28		1.05**	1.18	1.30	1.01	
RR(min^{-1}):2:30 p.m.	Tap(Ctrl)	27.05^{c1}	45^{a1}	44.6^{a1}	38.2^{b1}	1.10^{**}	53.8^{a2}	51.4^{a2}	53.2^{a2}	52.0^{a2}	1.0
	Saline(Treat)	26.8^{d1}	44.4^{a1}	40.6^{b1}	33.6^{c2}	0.97^{**}	61.6^{b1}	66.8^{ab1}	72.8^{a1}	61.3^{b1}	1.7
S.E.		0.62	0.92	1.14	1.15		2.29**	1.84**	3.01**	2.08	

[a,b,c,d] Within the season, mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

[1,2] Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error; * $p<0.01$; ** $p<0.001$

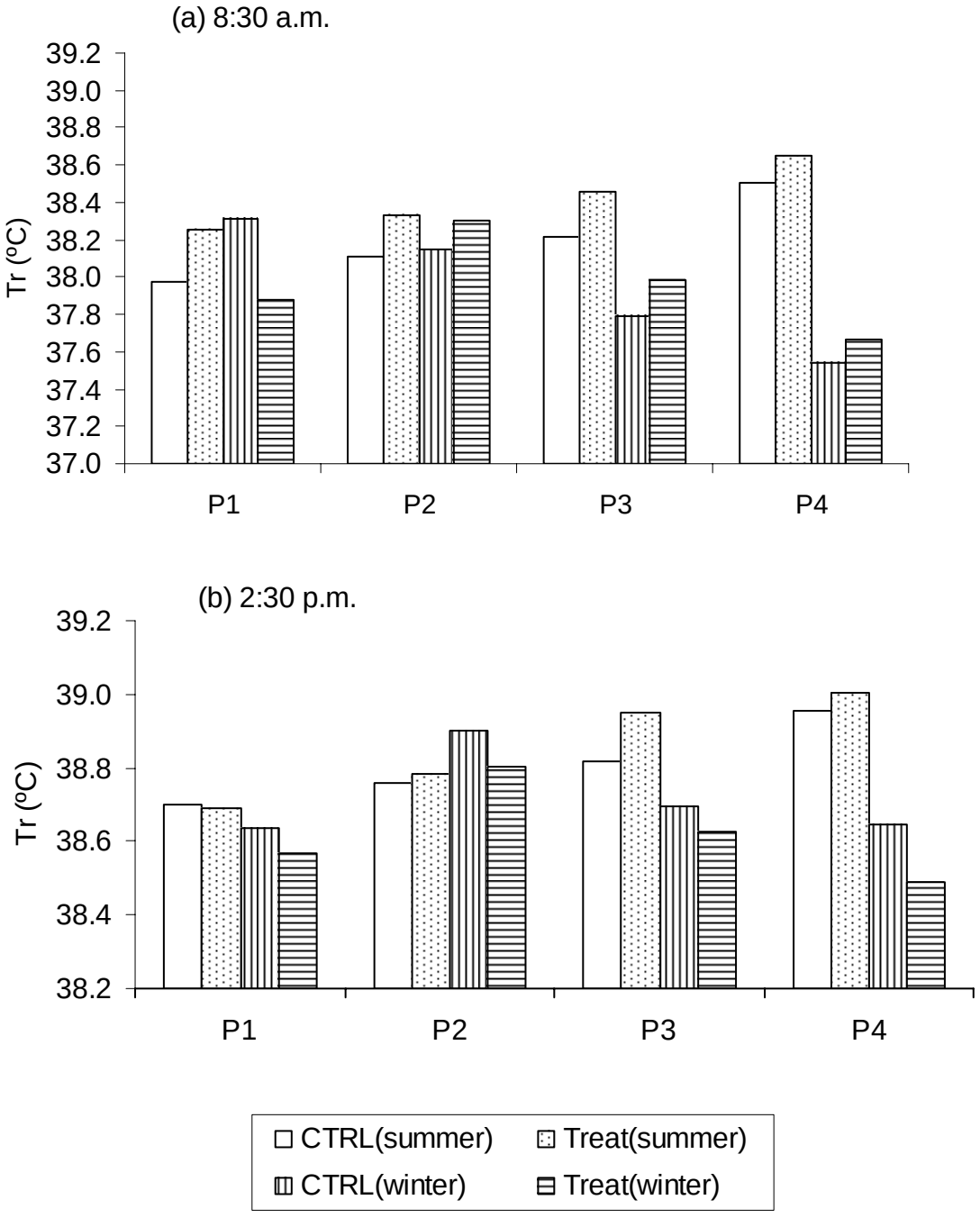


Fig. 3 Effect of salinity of drinking water and season on rectal temperature (Tr).

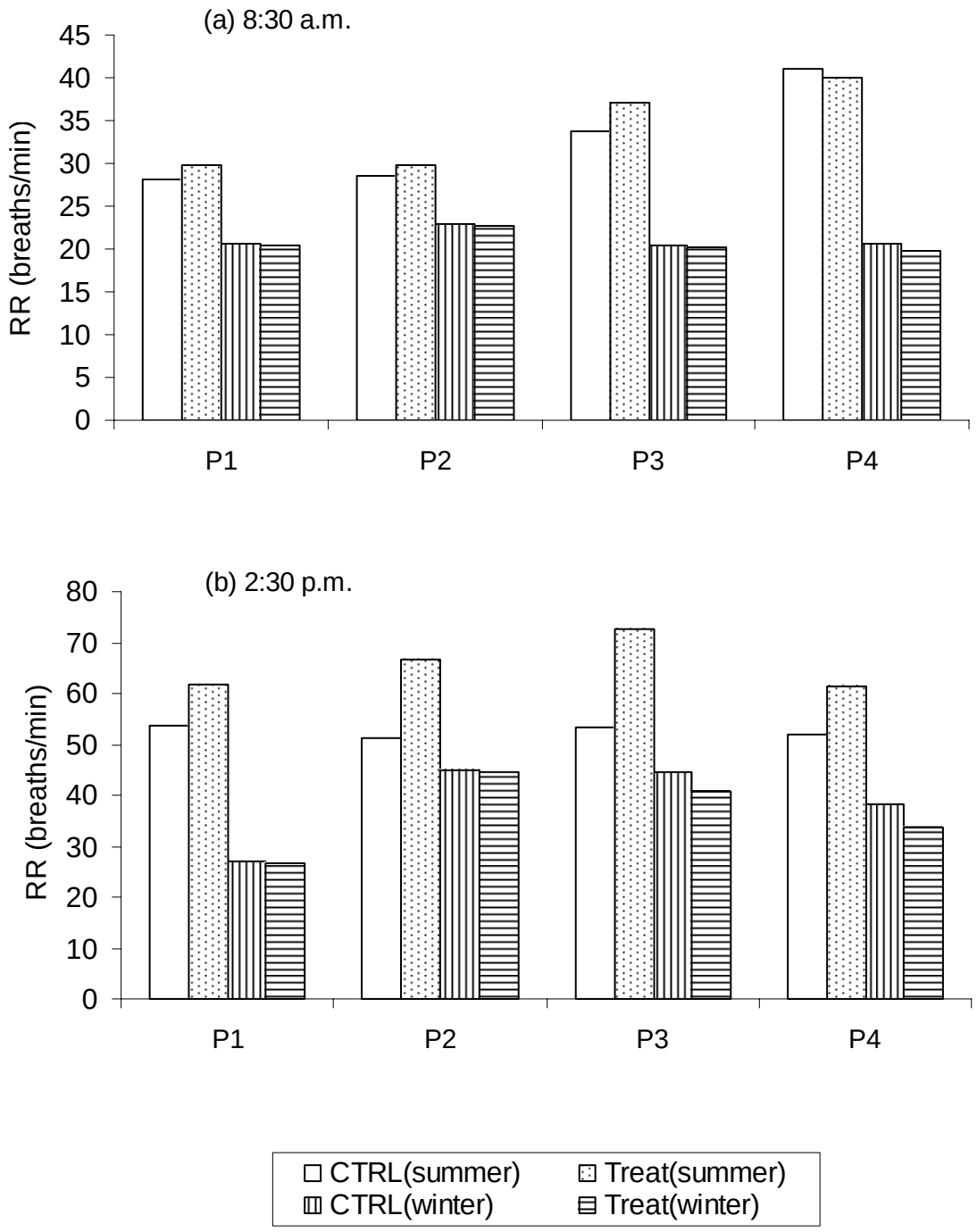


Fig. 4 Effect of salinity of drinking water and season on the respiration rate (RR).

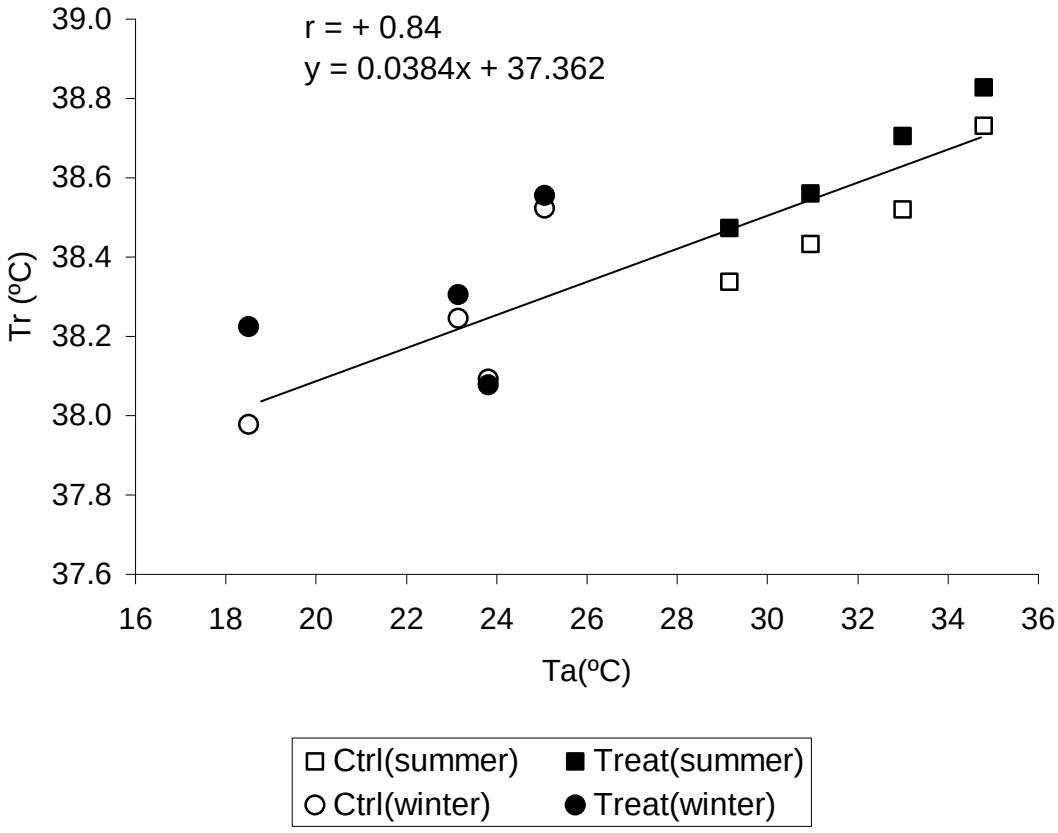


Fig. 5 Relation between ambient temperature (Ta) and rectal temperature (Tr).

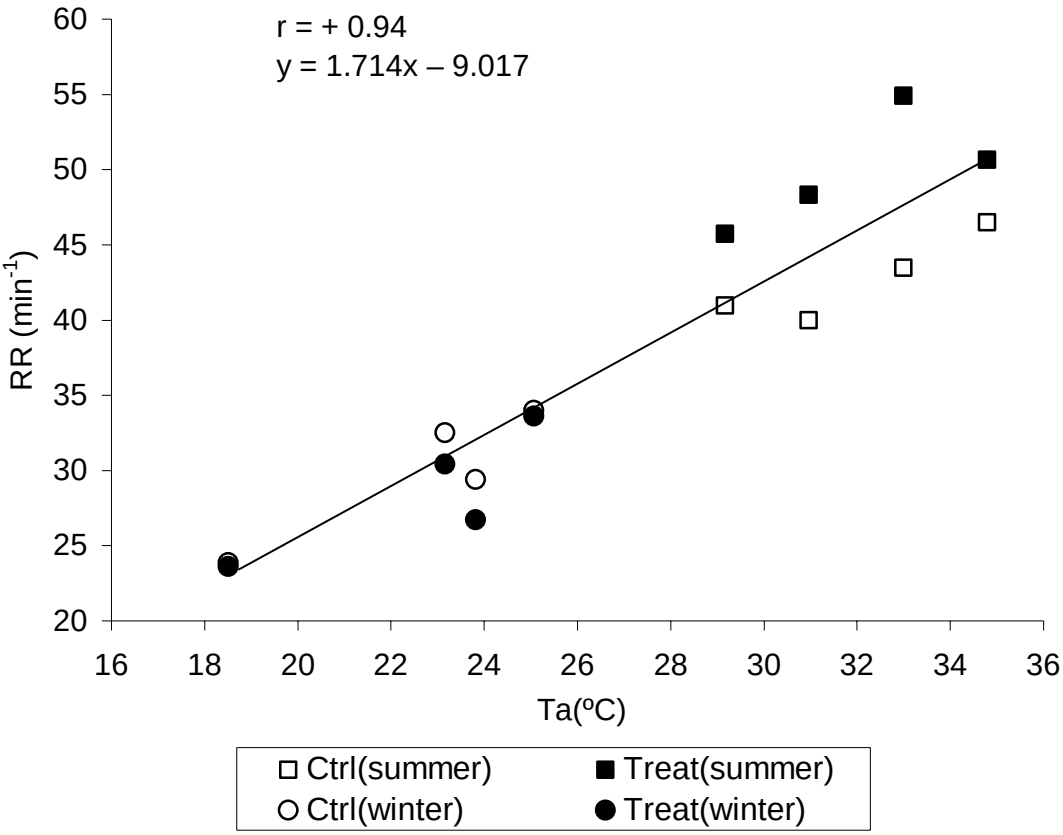


Fig. 6 Relation between ambient temperature (Ta) and respiratory rate (RR)

3.3.3 Water intake

Table 4 shows the results of the effects of salinity of drinking water and season on water intake**.**

In both seasons, the water intake (ml/day) by treated groups was significantly higher ($p<0.05$) than the respective control group value during the experimental periods, except P1 (0.8%) and P4 (2%) in winter season. In winter, increasing of NaCl concentration increased water intake significantly ($p< 0.01$) from P1 to P2, then it decreased ($p< 0.001$) at P4. In control groups, water intake was higher ($p<0.01$) at P2 during winter and at P2 and P4 ($p< 0.05$) during summer compared with other control groups.

The computation of water intake in relation to metabolic body weight (ml/kg$W^{0.75}$) (Fig. 7) showed that, in both seasons, the intake of water was significantly higher for treated groups than respective control groups except at P1 in both seasons and P4 in summer. With increasing of NaCl concentration, in both seasons water intake tended to increase from P1 (0.8% NaCl) to P2 (1.2% NaCl), then it decreased at P3 (1.6% NaCl) and further decreasing at P4 (2.0% NaCl).

Water intake by goats was affected by seasons. In both control and treated groups, the intake of water in the summer was higher compared to the respective winter values. There was a positive correlation ($r = + 0.85$) between water intake (ml/kg$W^{0.75}$) and ambient temperature as shown in Fig.8.

Table 4. The effect of salinity of drinking water on water intake and sodium chloride intake of Nubian goats during winter and summer. (n = 40, mean ± SE.M.)

Parameter		Water type	Winter					Summer				
			Experimental period				S.E.	Experimental period				S.E.
			P1	P2	P3	P4		P1	P2	P3	P4	
Water intake(ml/day)		Tap(Ctrl)	1660^{b1}	1955^{a2}	1574^{b2}	1583^{b1}	43.3^{*}	2844^{b2}	3438^{a2}	3096^{ab2}	3246^{a2}	67.7
		Saline(Treat)	1807^{b1}	2671^{a1}	2265^{ab1}	1708^{b1}	101^{*}	3712^{a1}	4657^{a1}	4668^{a1}	4447^{a1}	146
	S.E.		76.6	120*	131*	102		137*	145**	179**	217*	
Water intake(ml/ $kgW^{0.75}$)		Tap(Ctrl)	176^{b1}	204^{a2}	160^{b2}	157^{b1}	4.60^{**}	330^{b1}	376^{a2}	306^{b2}	322^{b2}	7.93
		Saline(Treat)	180^{b1}	261^{b1}	221^{b1}	170^{b1}	9.46^{*}	349^{a1}	443^{a1}	419^{a1}	403^{a1}	12.8
	S.E.		7.38	11.3	12.2	9.73		13.4	13.5	15.2**	18.7*	
Sodium chloride intake from saline water (g/day)		Saline(Treat)	14.46^{b}	32.05^{a}	36.24^{a}	34.16^{a}	1.63^{**}	29.6^{d}	55.88^{c}	74.68^{b}	88.9^{a}	2.99^{**}

^{a,b,c,d} within the season, mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

^{1,2} mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error.

* $p<0.01$.

** $p<0.001$.

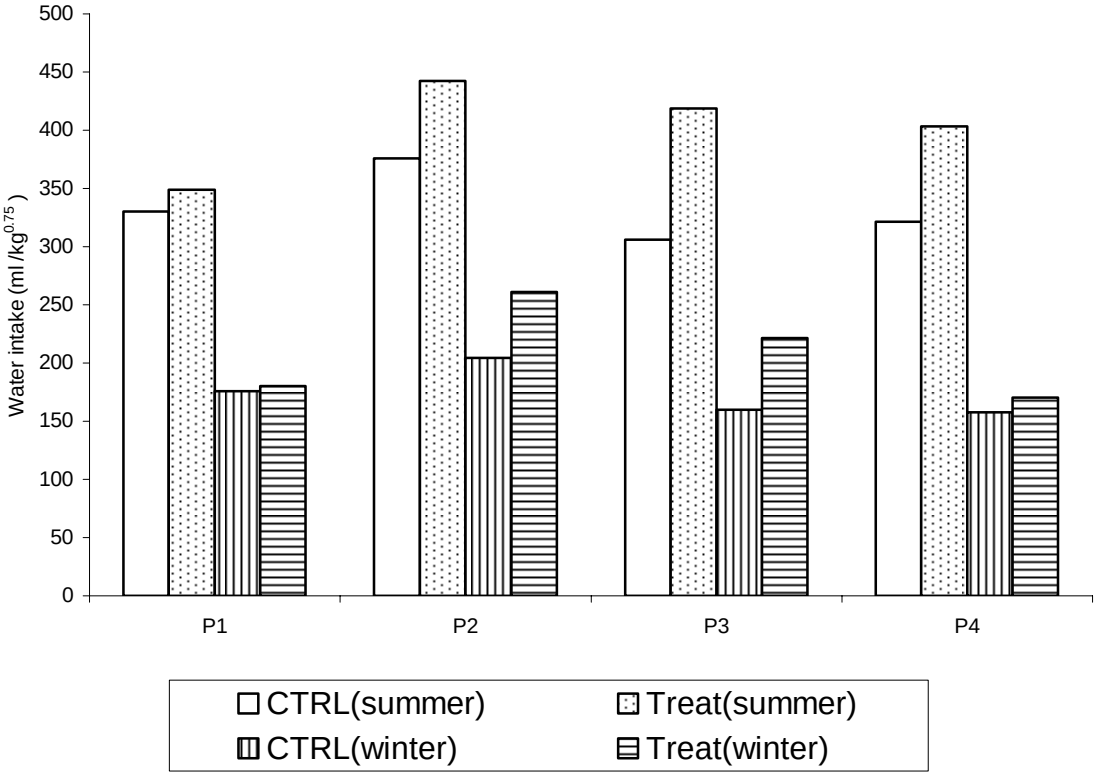


Fig. 7 Effect of salinity of drinking water and season on water intake.

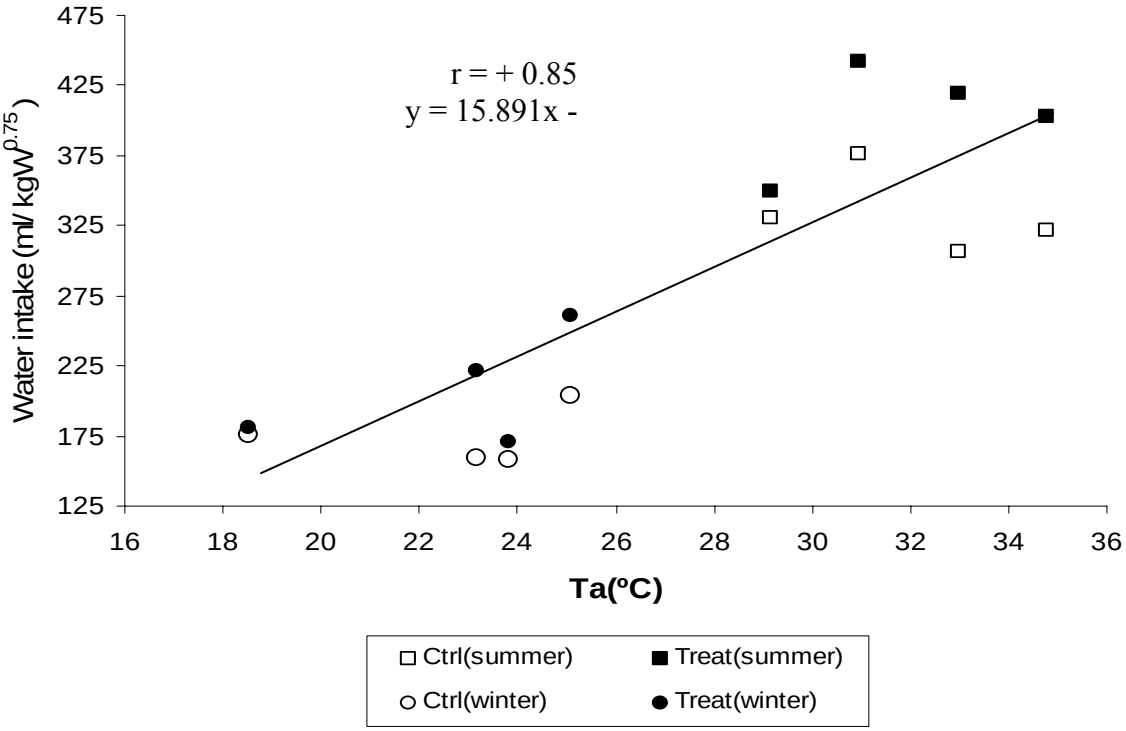


Fig. 8 Relation between ambient temperature (Ta) and water intake (ml/kg$^{0.75}$)

3.3.4 Intake of sodium chloride

Table 4 shows the mean daily intake values of sodium chloride (g/day) from the drinking water by the goats during both seasons (Fig. 9).

In summer, the intake of NaCl (g/day) increased significantly ($p<0.001$) with increasing NaCl concentration. In winter, NaCl intake increased significantly with increase NaCl concentration from 0.8% to 1.2% NaCl in drinking water. The mean values of NaCl intake in summer were higher than the respective winter value. Fig. 10 shows that there was a positive correlation ($r = + 0.77$) between NaCl intake (g/day) and water intake (ml/kg$W^{0.75}$) for treated group.

3.3.5 Food intake

Table 5 shows the results of the effects of salinity of drinking water and season on food intake**.**

In both seasons, the food intake (g/kg$^{0.75}$) was significantly lower in treated groups compared to the control groups' values during the experimental periods, except P1 in winter and P2 in summer as shown in Fig. 11. In summer, the food intake for treated groups increased significantly ($p< 0.001$) with increasing NaCl concentration from P1 to P2, and then it decreased ($p< 0.001$) at P4. In winter, the highest value of food intake for the treated groups were recorded at P1 and P2, which did not differ from each other. The mean values of food intake by the control group in summer was higher than in winter. For treated groups the food intake was higher in winter compared to summer value.

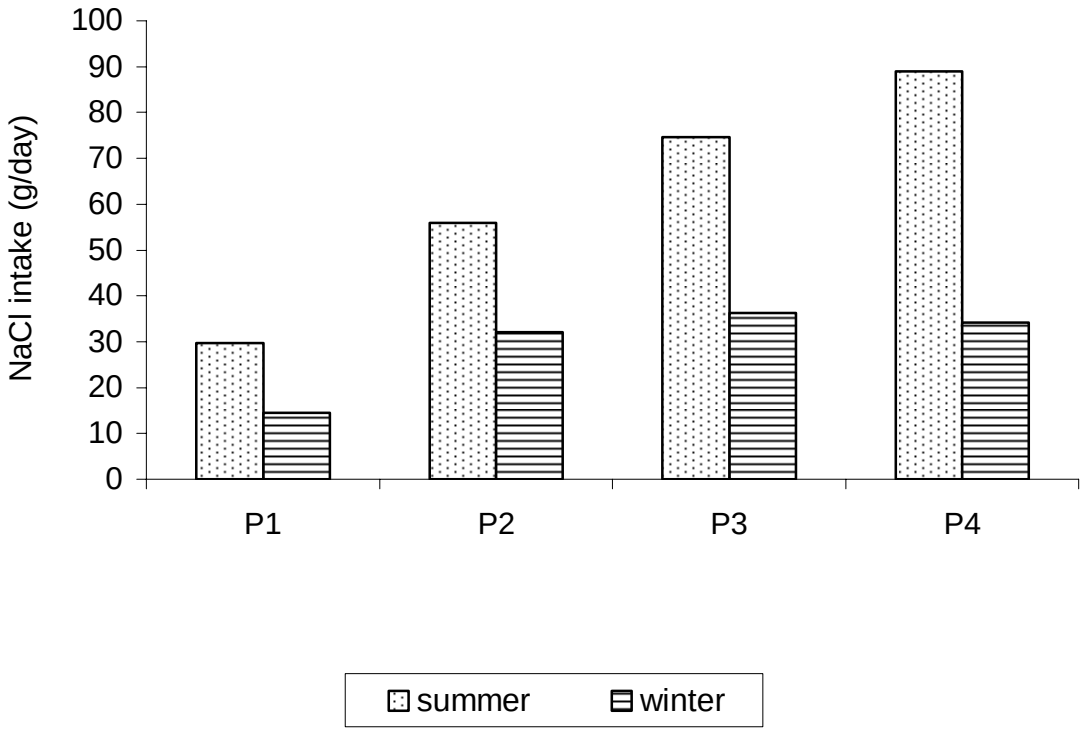


Fig. 9 Mean daily sodium chloride intake by goats from offered varying levels of NaCl in drinking water (0.8, 1.2, 1.6, 2% NaCl) (Treat) for 4 consecutive periods (each 10 days) during winter and summer.

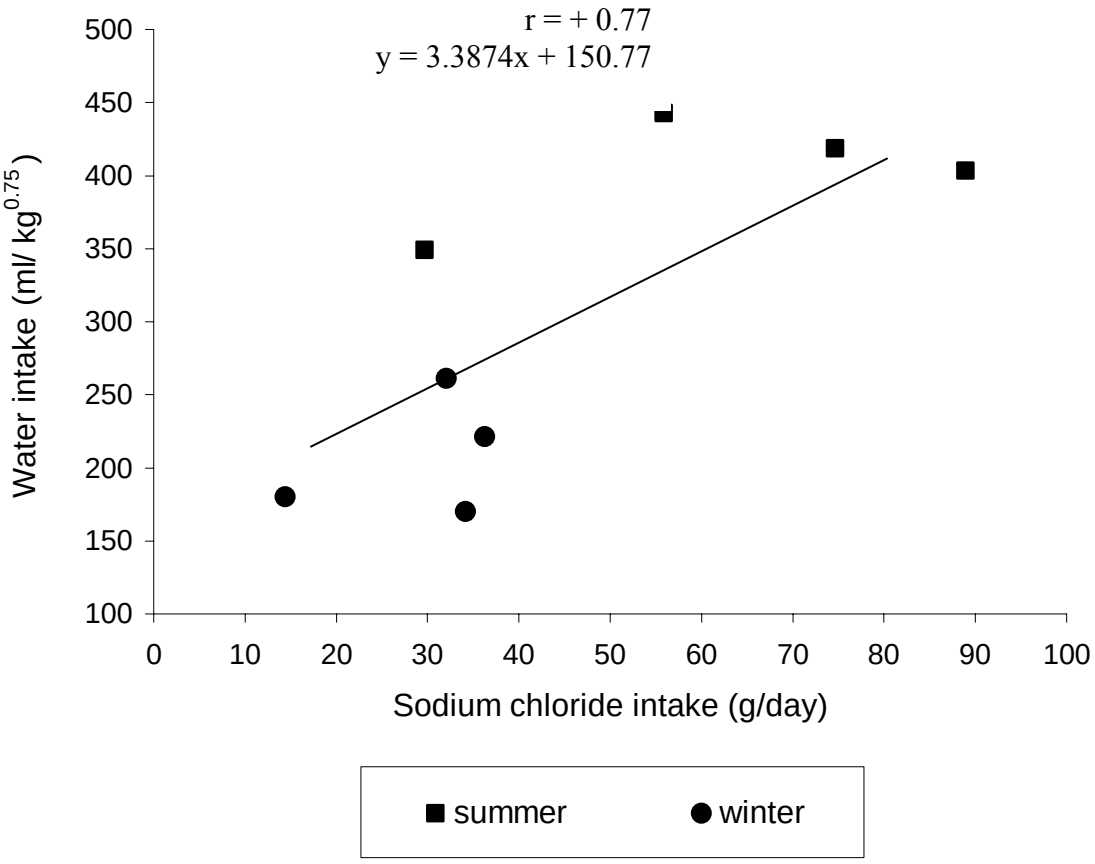


Fig. 10 Relation between NaCl intake (g/day) and water intake (ml/kg$^{0.75}$)

The data obtained for all experimental groups shows that there was a negative correlation (r = – 0.24) between feed intake and ambient temperature (Fig. 12).

The ratio between the intake of water and feed intake (litre/Kg) is presented in Table 5. The treated groups had significantly higher values compared to respective control values in all experimental periods, except P1 and P4 in winter.

3.3.6 Body weight

The mean body weight values of each group for each period during winter and summer are presented in Table 5 and illustrated in Fig. 13.

In both seasons, the changes in body weight was not significant between control and treated groups except in P3 during winter in which the body weight of the control was significantly higher ($p<0.05$) compared to the treated group. In summer, the highest values the body weight were recorded at P2 for control as well as treated group.

There was a positive correlation (r = + 0.47) between body weight gain and feed intake (Fig. 14).

Table 5: The effect of salinity of drinking water on feed intake and body weight gain of Nubian goats during winter and summer.

Parameter	Water type	Winter					Summer				
		Experimental period				S.E.	Experimental period				S.E.
		P1	P2	P3	P4		P1	P2	P3	P4	
Feed intake (g/day)	Tap(Ctrl)	1057^{a1}	1080^{a1}	928^{b1}	860^{b1}	16.6**	919^{b1}	1023^{a1}	989^{ab1}	956^{b1}	13.95**
	Saline(Treat)	1007^{a1}	1062^{a1}	725^{b2}	734^{b2}	18.2**	911^{b1}	1081^{a1}	893^{b2}	633^{c2}	20.7**
	S.E.	26.1	18.6	25.4**	19.5**		26.0	21.7	19.9	22.1**	
Feed intake(g/kgBW$^{0.75}$)	Tap(Ctrl)	112^{a1}	112^{a1}	95^{b1}	85^{c1}	1.61**	105^{a1}	111^{a1}	98^{b1}	95^{b1}	1.58**
	Saline(Treat)	102^{a1}	104^{a2}	71^{b2}	73^{b2}	1.82**	86^{b2}	103^{a1}	81^{b2}	58^{c2}	2.05**
	S.E.	2.50	1.67	2.49**	1.74**		2.74**	2.41	2.13**	2.4**	
Ratio: water to feed (L/kg)	Tap(Ctrl)	1.6^{a1}	1.8^{a2}	1.7^{a2}	1.9^{a1}	0.05	3.1^{a2}	3.4^{a2}	3.1^{a2}	3.4^{a2}	0.08
	Saline(Treat)	1.8^{b1}	2.5^{ab1}	3.2^{a1}	2.3^{a1}	0.10*	4.1^{b1}	4.3^{b1}	5.2^{b1}	7.0^{a1}	0.29**
	S.E.	0.09	0.12*	0.19**	0.13		0.16*	0.15**	0.26**	0.44**	
Change in body weight (kg)	Tap(Ctrl)	2.25^{a1}	-0.75^{b1}	1.5^{a1}	0.25^{ab1}	0.42	-2.13^{b1}	4.63^{a1}	0.75^{b1}	-1.13^{b1}	0.78*
	Saline(Treat)	0.75^{a1}	0.63^{a1}	-0.75^{a2}	0.0^{a1}	0.32	-1.75^{b1}	1.88^{a1}	0.75^{a1}	-1.5^{b1}	0.54
	S.E.	0.61	0.54	0.58	0.16		0.62	0.91	0.51	0.37	

[a,b,c,d] Within the season, mean values within the same row bearing different superscripts (letter) are significantly different at $p<0.05$.

[1,2] Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error. * $p<0.01$. ** $p<0.001$.

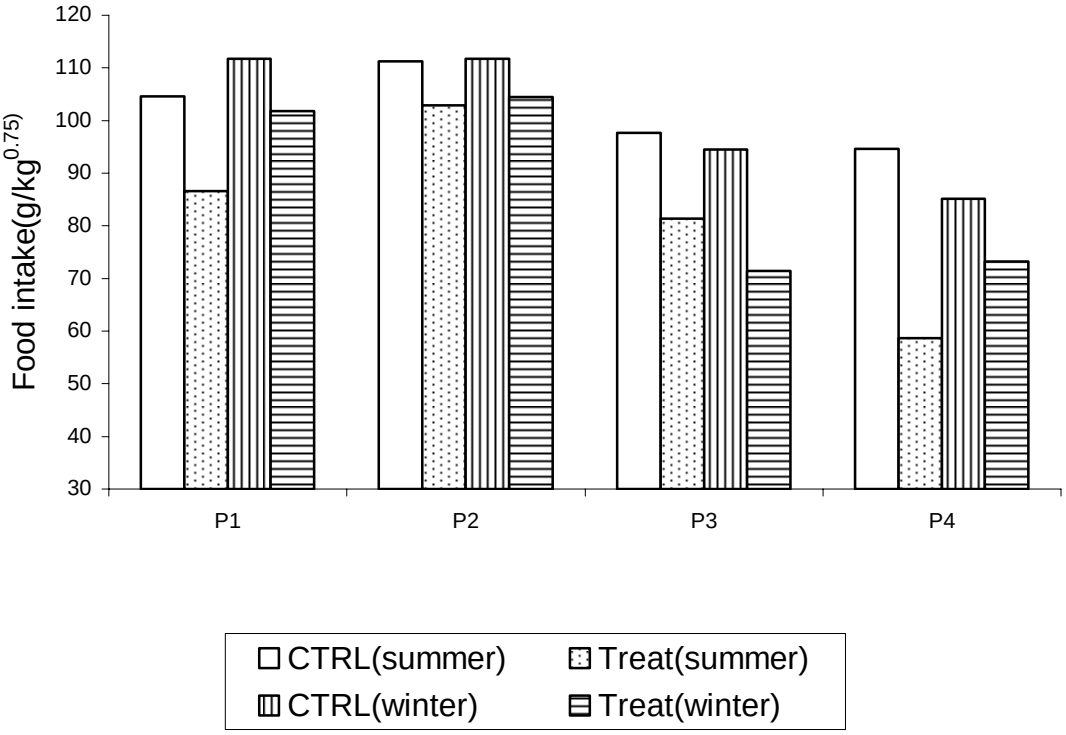


Fig. 11 Effect of salinity of drinking water and season on food intake.

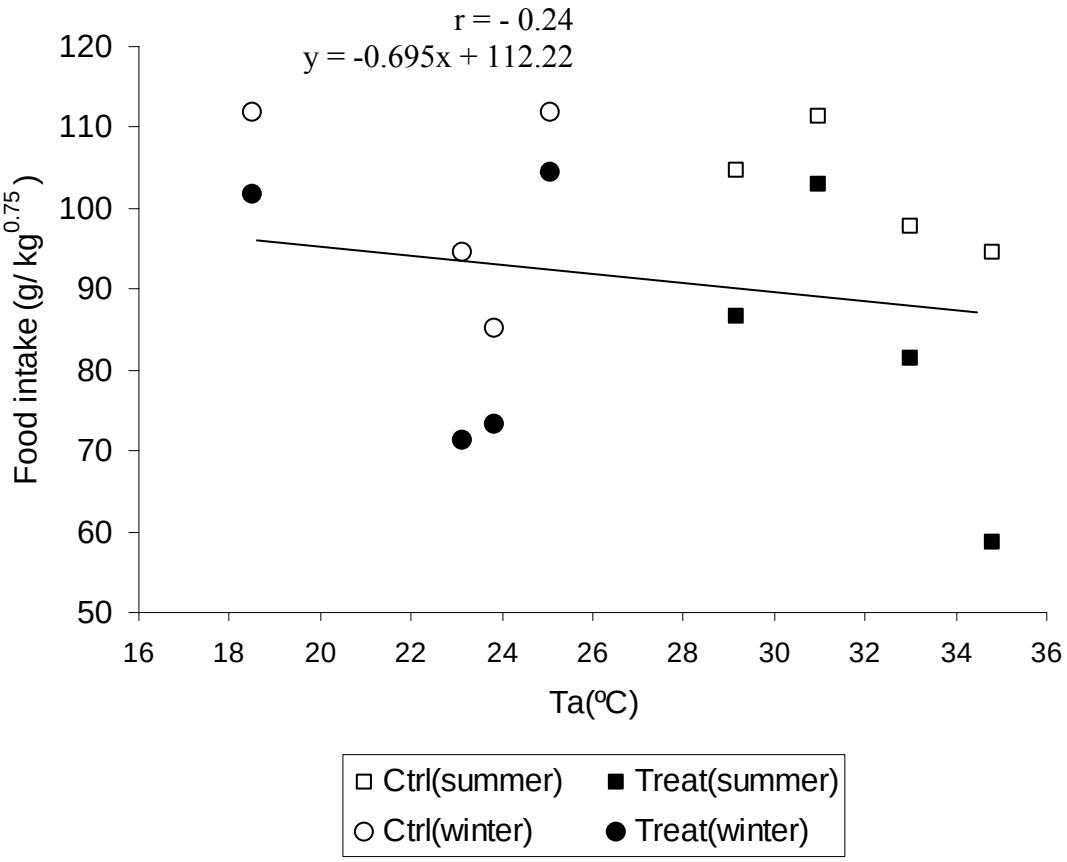


Fig. 12 Food intake (g/kg$^{0.75}$) plotted against ambient temperature (Ta).

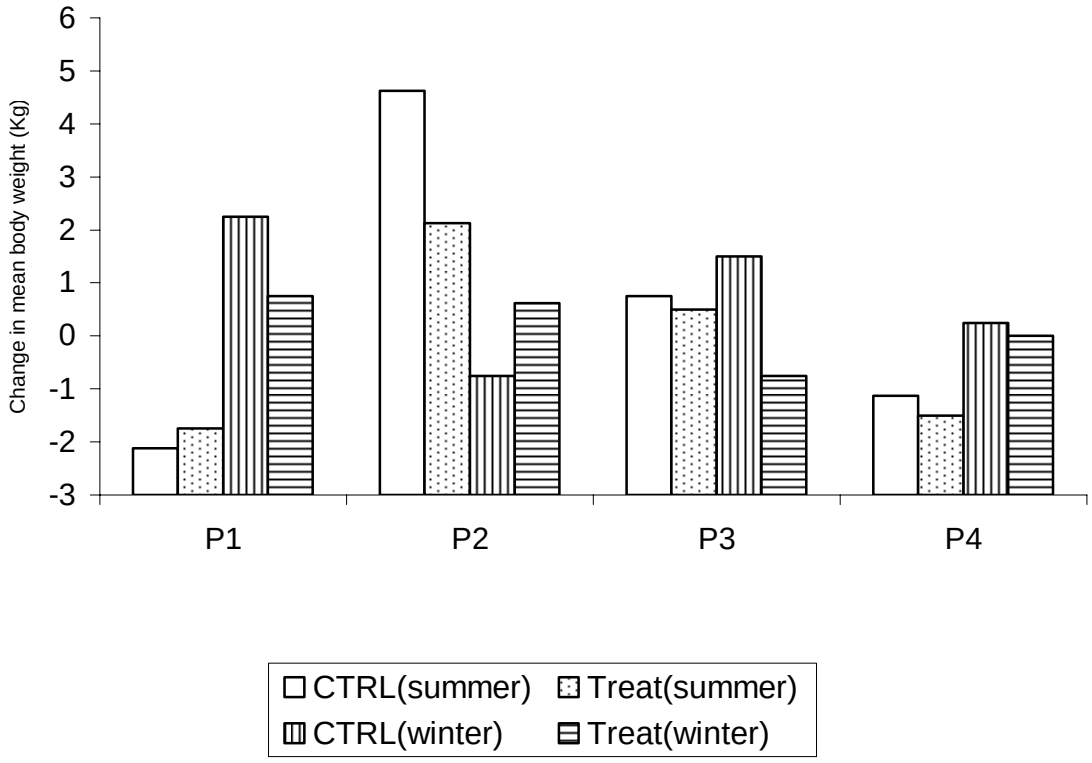


Fig. 13 Effect of salinity of drinking water and season on body weight.

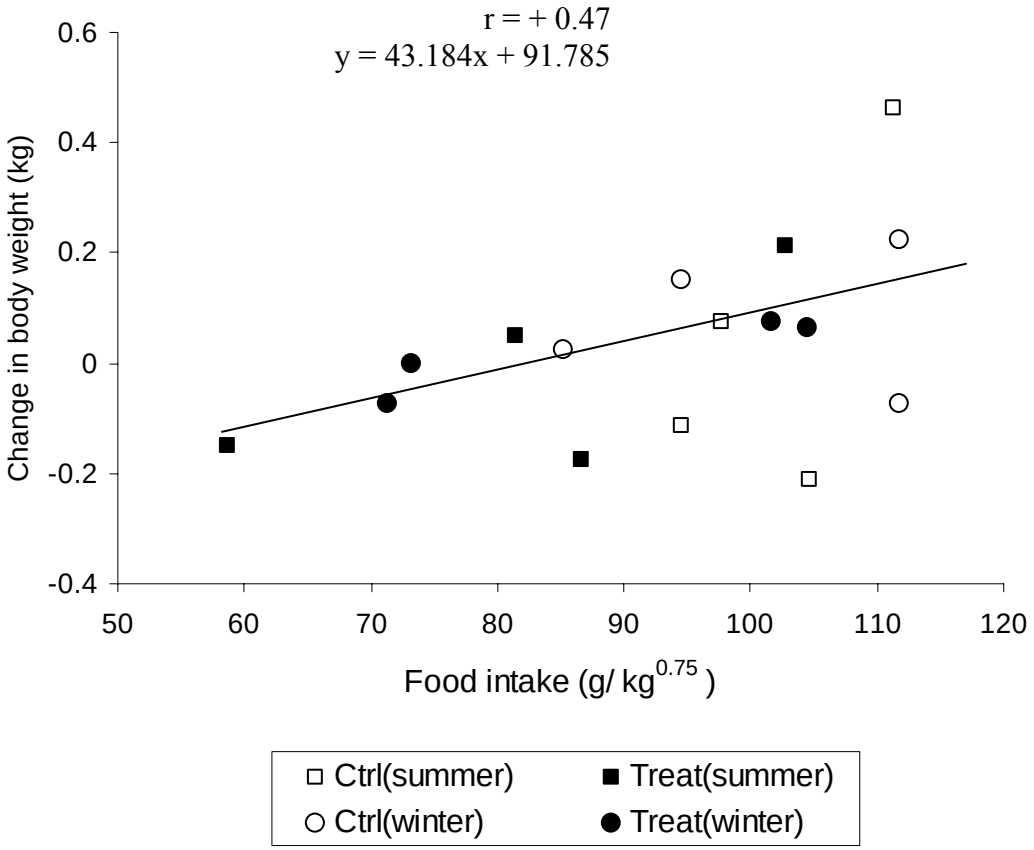


Fig. 14 Relation between body weights gain (kg/day) and feed intake (g/kg$^{0.75}$)

3.3.7 Packet cell volume (PCV) and haemoglobin concentration (Hb)

Table 6 shows the effects of salinity of drinking water and season on packed cell volume (PCV %) and haemoglobin concentration (Hb).

In both seasons, the PCV (Fig. 15) and Hb (Fig. 17) had no different between the control and treated groups except the PCV during P2 and P3 in summer season. The response of blood of goats with increasing NaCl concentration was significantly ($p<0.01$) different in winter season only. The highest values of Hb and PCV for treated groups were recorded during P4 (2% NaCl), while the lowest values were obtained during P1 for Hb and during P2 for PCV.

The PCV of control and treated groups was higher in winter by 11 and 21%, respectively than those in summer season, thus there was a negative correlation between PCV and ambient temperature ($r = – 0.73$) as shown in Fig. 16. The Hb concentration was higher in summer by 1.7 and 1.1%, respectively than winter season, and there was a positive correlation between Hb and ambient temperature ($r = + 0.34$) as shown in Fig. 18.

3.3.8 Plasma glucose level

The data on plasma glucose level for the goats offered tap water (control) and varying concentrations of saline water (treated groups) for 4 consecutive periods during winter and summer are presented in Table 6.

In both seasons, the plasma glucose level (mg/dl) was not significantly different between control and treated groups during the experimental periods except in P1 during winter. The results showed the highest and lowest values

Table 6: The effects of salinity of drinking water on packet cell volume (PCV), haemoglobin concentration (Hb) and plasma glucose level of Nubian goats during winter and summer.

Parameters	Water type	Winter					Summer				
		Experimental period				S.E.	Experimental period				S.E.
		P1	P2	P3	P4		P1	P2	P3	P4	
PCV (%)	Tap(Ctrl)	23.5^{a1}	22.42^{a1}	23.75^{a1}	24.75^{a1}	0.56	22.33^{a1}	21.67^{a1}	21.17^{a1}	20.17^{a1}	0.41
	Saline(Treat)	23^{b1}	20.25^{c1}	23.33^{ab1}	25.83^{a1}	0.53^{*}	19.58^{a1}	18.25^{a2}	19.0^{a2}	19.25^{a1}	0.40
	S.E.	0.81	0.65	0.71	0.69		0.73	0.68*	0.55	0.49	
Hb (g/dl)	Tap(Ctrl)	10.31^{b1}	12.48^{a1}	11.57^{ab1}	12.04^{ab1}	0.31^{*}	11.57^{ab1}	12.24^{a1}	11.97^{ab1}	11.42^{b1}	0.13
	Saline(Treat)	10.20^{c1}	10.90^{bc1}	11.69^{ab1}	12.64^{a1}	0.24^{**}	11.18^{a1}	11.93^{a1}	11.34^{a1}	11.50^{a1}	0.22
	S.E.	0.29	0.52	0.29	0.29		0.24	0.27	0.24	0.26	
Glucose (g/dl)	Tap(Ctrl)	53.26^{a2}	57.95^{a1}	45.83^{b1}	52.27^{ab1}	1.29^{*}	49.62^{a1}	56.44^{a1}	55.30^{a1}	54.17^{a1}	1.33
	Saline(Treat)	59.85^{a1}	60.98^{a1}	53.03^{b1}	55.68^{ab1}	1.16	56.82^{a1}	60.61^{a1}	55.30^{a1}	57.95^{a1}	1.24
	S.E.	1.16*	1.62	1.90	1.86		2.04	1.86	1.91	1.52	

^{a,b,c,d} Within the season, mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

^{1,2} Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error.

* $p<0.01$.

** $p<0.001$.

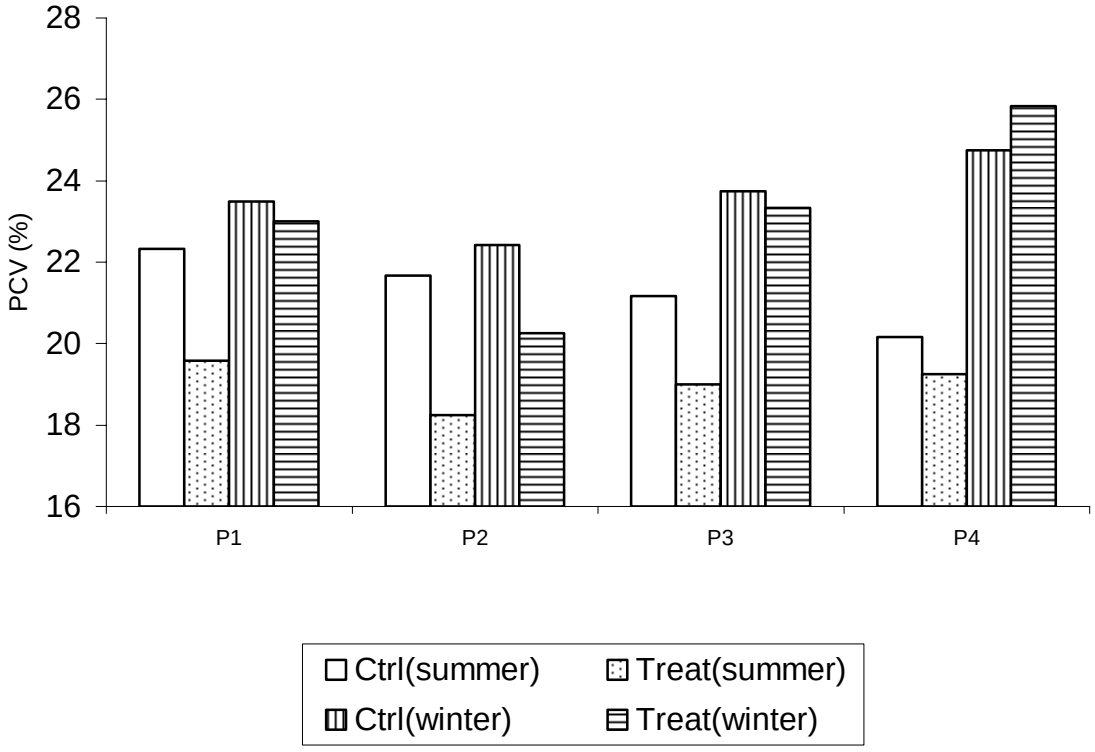


Fig. 15 Effect of salinity of drinking water and season on packed cell volume (PCV).

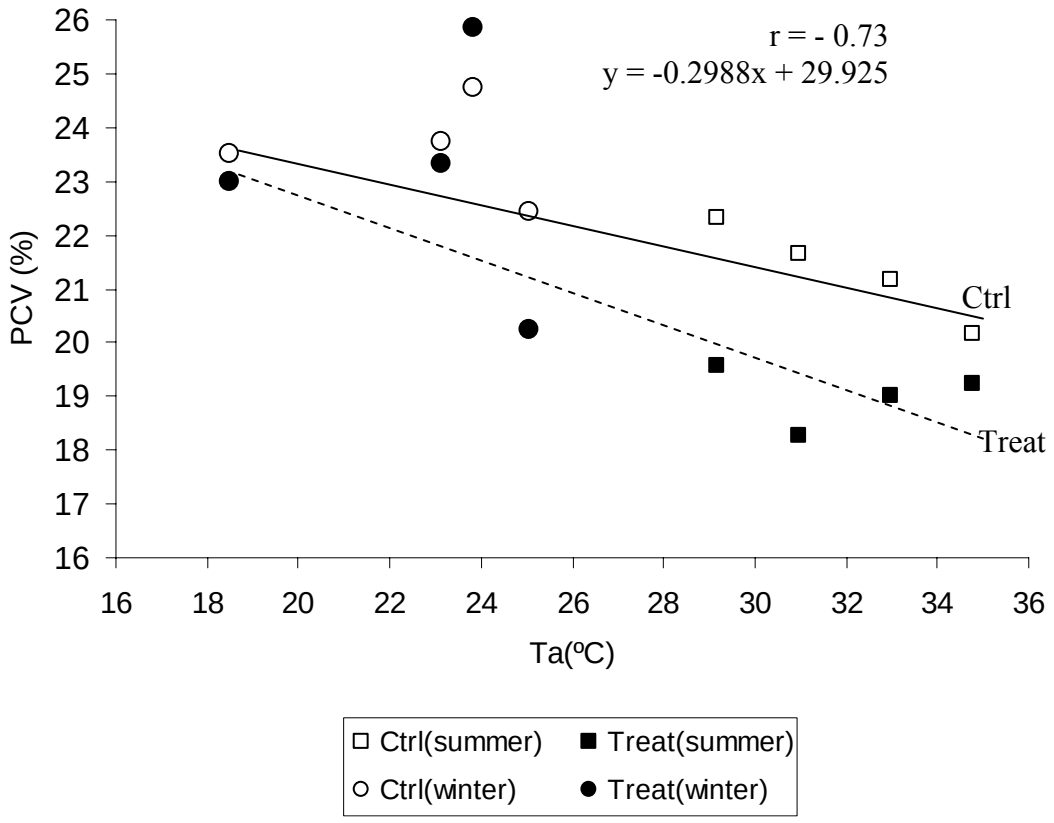


Fig. 16 Relation between ambient temperature (Ta) and PCV level

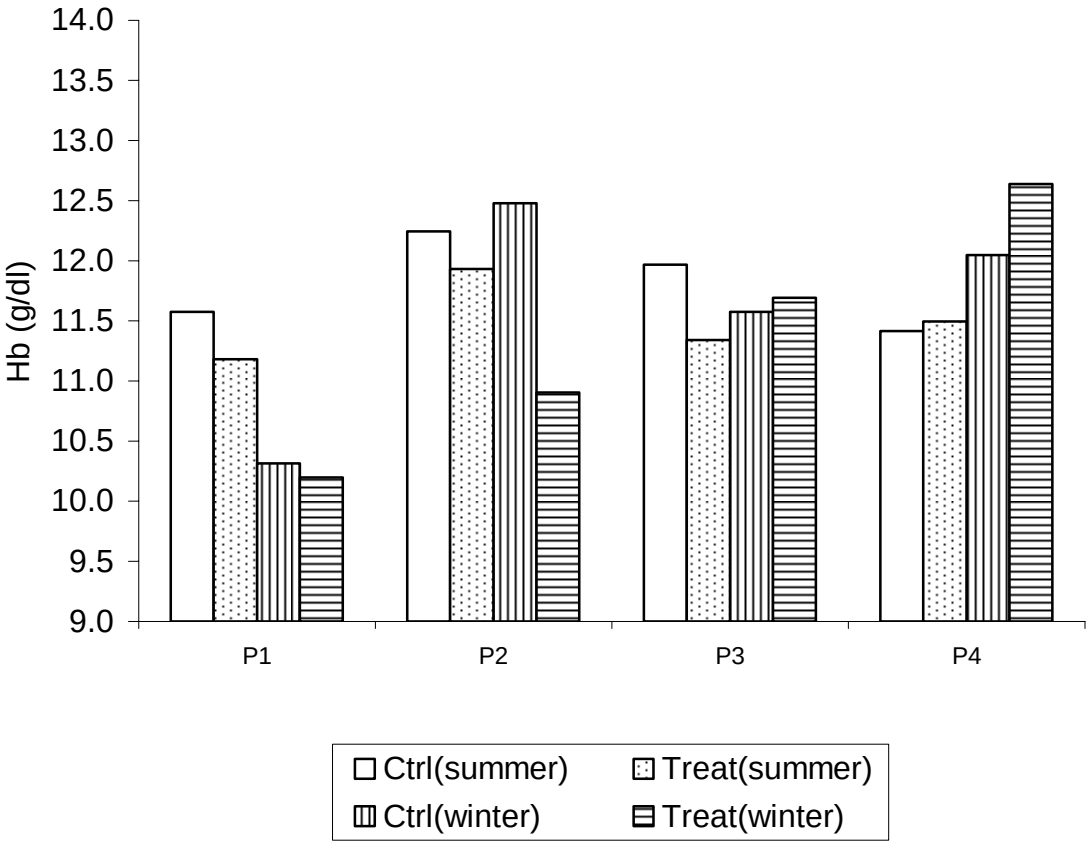


Fig. 17 Effect of salinity of drinking water and season on haemoglobin concentration (Hb).

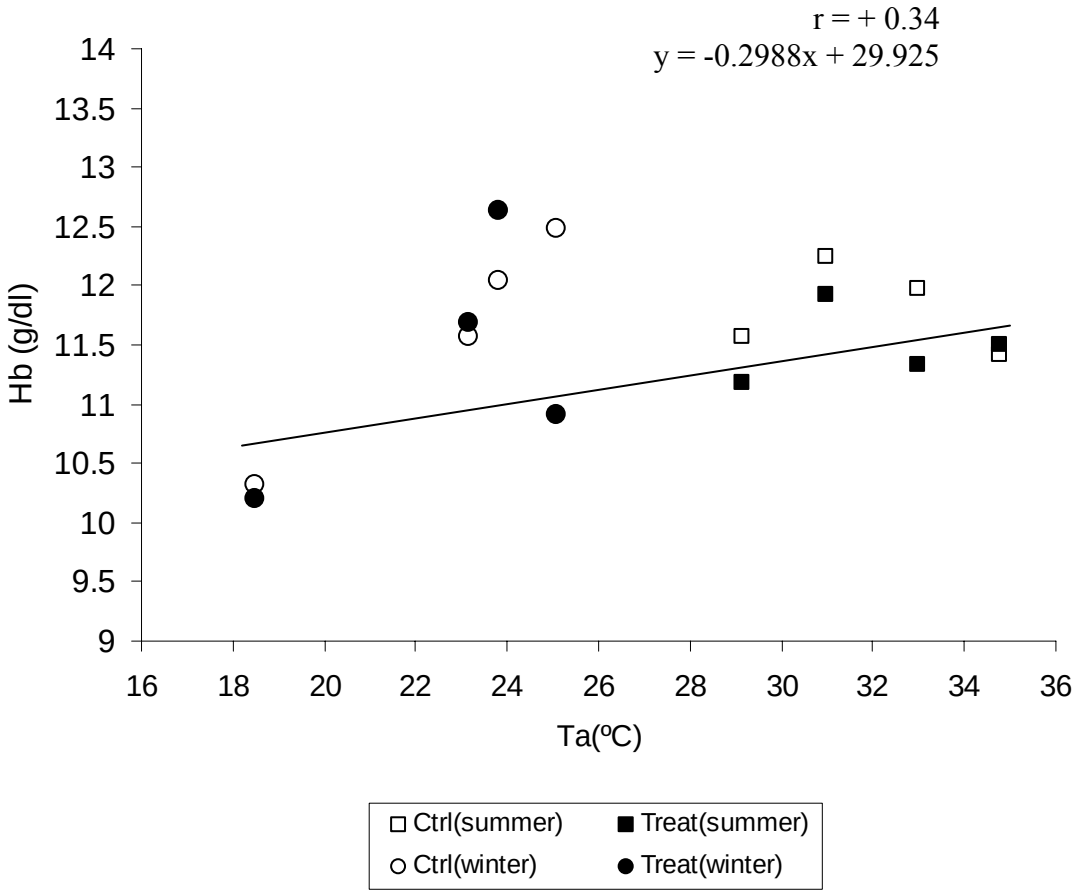


Fig. 18 Relation between ambient temperature (Ta) and haemoglobin concentration (Hb).

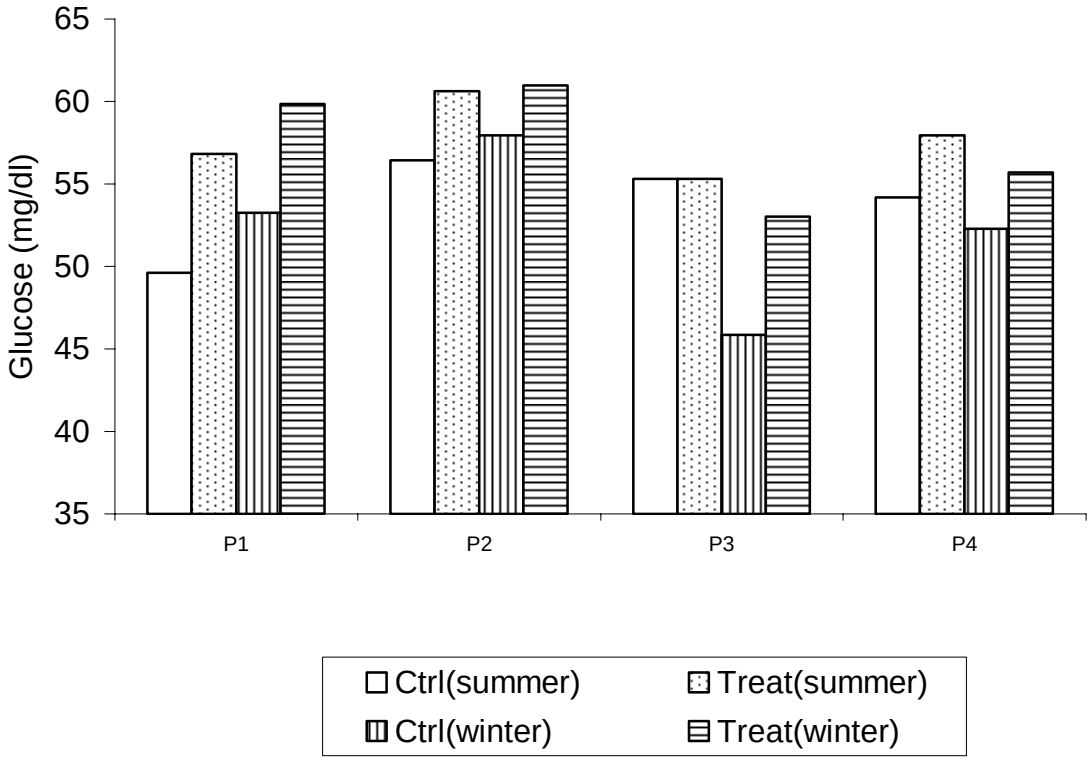


Fig. 19 Effect of salinity of drinking water and season on plasma glucose level.

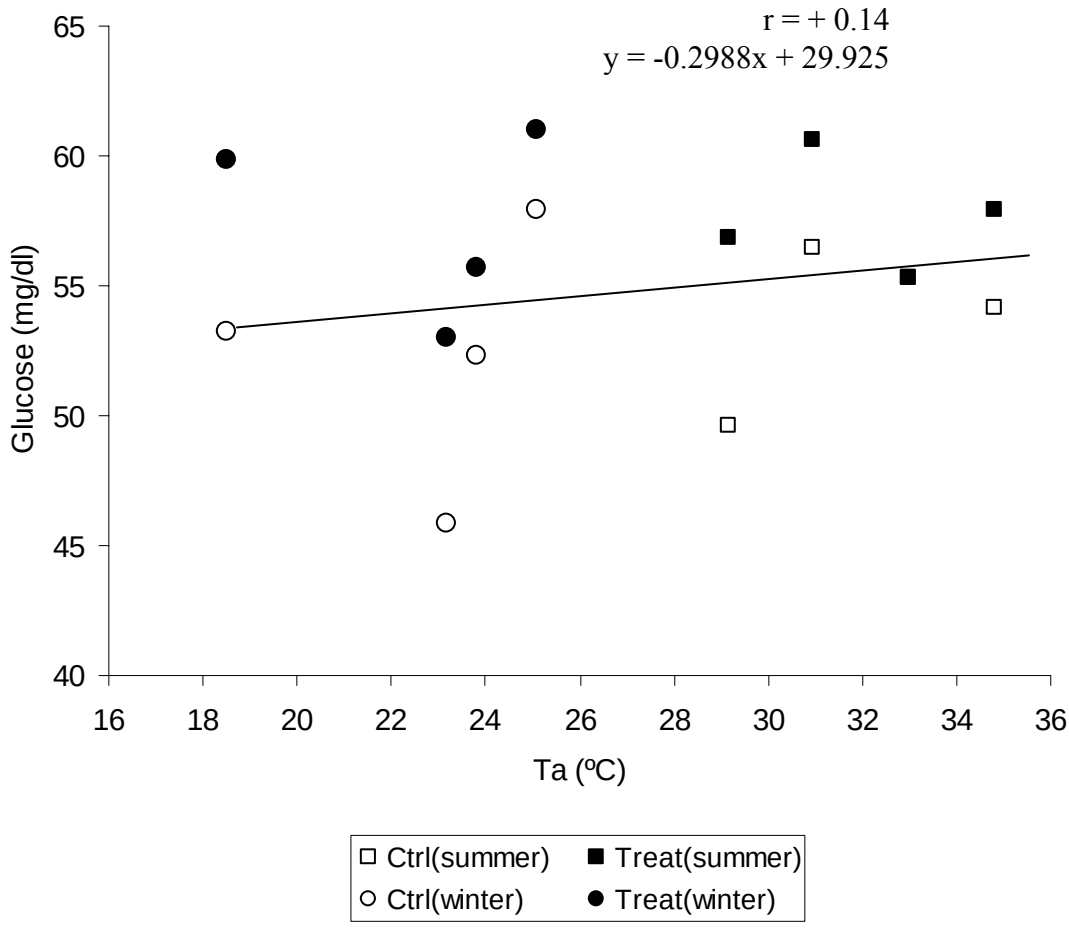


Fig. 20 Relation between ambient temperature (Ta) and plasma glucose level.

at P2 and P3, respectively in winter for the control as well as treated groups (Fig. 19). The plasma glucose level of control and treated groups was higher in summer by 3 and 0.5%, respectively than the respective winter values and there was a positive correlation (r = + 0.14) between plasma glucose level and ambient temperature as shown in Fig. 20.

3.3.9 Serum total protein (Tp), albumin (Alb) and urea

Table 7 shows the results of the effects of salinity of drinking water and season on serum total protein (Tp), albumin (Alb) and urea.

In both seasons, drinking saline water increased serum total protein and albumin concentrations significantly compared with the control groups except at P1 (Fig. 21 a,b). Increasing NaCl concentration in drinking water increased Tp and Alb significantly ($p<0.001$) from P1 to P4. However, the increase in Alb concentration between P2 and P3 was not significant (Fig. 21b).

In both seasons, drinking saline water increased serum urea concentration significantly (Table 7) compared with the control group values, except at P4. In both seasons, increasing NaCl concentration in drinking water decreased urea concentration significantly ($p<0.001$) from P1 to P4. However, the decrease between P3 and P4 was not significant ($p>0.05$) (Fig. 21 c).

Table 7: The effects of salinity of drinking water on serum metabolites of Nubian goats during winter and summer.

Parameter	Water type	Winter					Summer				
		Experimental period				S.E.	Experimental period				S.E.
		P1	P2	P3	P4		P1	P2	P3	P4	
Total protein (g/dl)	Tap(Ctrl)	7.33^{a1}	7.4^{a2}	7.45^{a2}	7.48^{a2}	0.03	6.73^{b1}	6.79^{ab2}	6.93^{a2}	6.90^{a2}	0.03
	Saline(Treat)	7.3^{d1}	7.52^{c1}	7.68^{b1}	7.81^{a1}	0.03^{**}	6.76^{a1}	7.02^{a1}	7.40^{a1}	7.58^{a1}	0.05^{**}
S.E.		0.4	0.03	0.04*	0.04**		0.02	0.03**	0.06**	0.08**	
Albumin (g/ dl)	Tap(Ctrl)	3.35^{a1}	3.49^{a2}	3.48^{a2}	3.43^{a2}	0.03	3.69^{a1}	3.63^{a1}	3.45^{b2}	3.72^{a1}	0.03^{*}
	Saline(Treat)	3.34^{c1}	3.64^{b1}	3.69^{b1}	3.80^{a1}	0.03^{**}	3.73^{a1}	3.80^{a1}	3.69^{a1}	3.80^{a1}	0.02
S.E.		0.04	0.03	0.03**	0.05**		0.03	0.04	0.64**	0.02	
Urea (mg/dl)	Tap(Ctrl)	20.29^{b2}	21.67^{a2}	22.25^{a2}	22.56^{a1}	0.22^{**}	21.25^{a2}	21.83^{a2}	21.92^{a2}	21.71^{a2}	0.30
	Saline(Treat)	28.0^{a1}	25.5^{b1}	23.23^{c1}	19.39^{d2}	0.48^{**}	27.17^{a1}	26.83^{a1}	25.25^{b1}	23.17^{c1}	0.27^{**}
S.E.		0.20	0.29*	0.44**	0.60**		0.29**	0.50**	0.64**	0.71**	

^{a,b,c,d} Within the season, mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

^{1,2} Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error.

* $p<0.01$.

** $p<0.001$

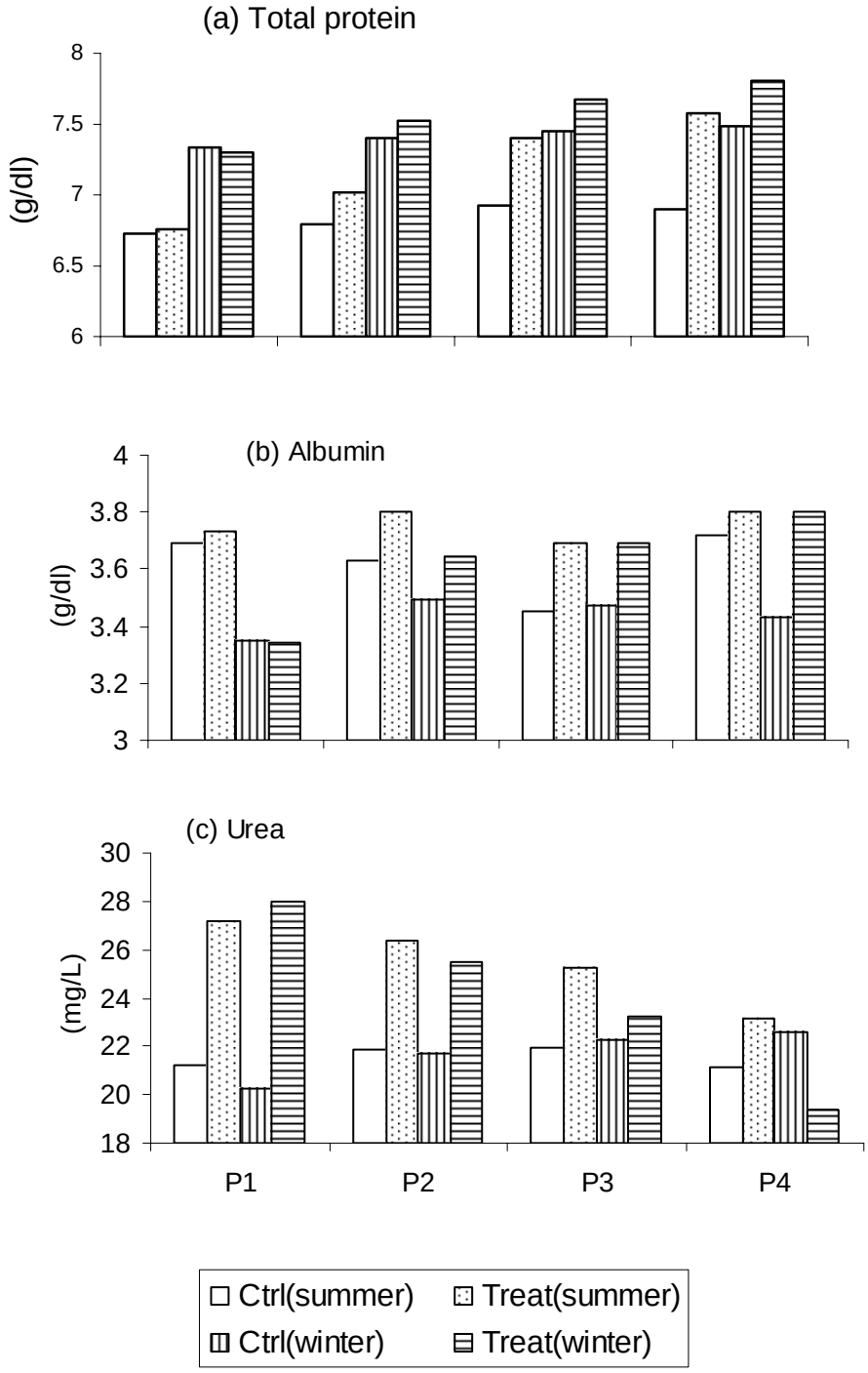


Fig. 21 Effects of salinity of drinking water and season on serum total protein, albumin and urea concentrations.

3.3.10 Serum electrolytes

Table 8 shows the results of the effects of salinity of drinking water and season on serum electrolytes of goats**.**

In both seasons, drinking saline water increased serum Na concentration significantly (Table 8) compared with the control groups except at P1 in summer. In summer, increasing of NaCl concentration in drinking water increased serum Na level significantly ($p<0.001$). In winter, the highest values of Na were recorded at P3 and P4 for the control as well as treated groups (Fig. 22 a). In both seasons, serum K level decreased significantly ($p<0.001$) with increasing NaCl concentration in drinking water (Fig. 22 b).

In winter, drinking saline water increased serum Mg concentration significantly (Table 8) compared with the control group except at P1, while in summer, the increase was observed at P4 only. For the control group, the highest values of serum Mg were recorded at P3 in summer, while in winter, the highest level was obtained at P2, which did not differ significantly from P1 and P4 (Fig.22 c).

Table 8: The effects of salinity of drinking water on serum electrolytes of Nubian goats during winter and summer.

Parameter	Water type	Winter					Summer				
		Experimental period				S.E.	Experimental period				S.E.
		P1	P2	P3	P4		P1	P2	P3	P4	
Na (mEq/L)	Tap(Ctrl)	145.2^{b2}	146^{b2}	155.5^{a2}	157.7^{a2}	1.36^{**}	152.8^{a2}	154.5^{a2}	154.8^{a2}	155.8^{a2}	0.59
	Saline(Treat)	159.9^{b1}	162.6^{b1}	169.2^{a1}	168.8^{a1}	1.02^{**}	157.2^{d1}	163.3^{c1}	168^{b1}	170.7^{a1}	0.85^{**}
S.E.		2.05**	2.22**	2.02**	1.80**		0.68**	1.11**	1.62**	1.7**	
K (mEq/L)	Tap(Ctrl)	4.31^{b2}	4.44^{ab2}	4.55^{a2}	4.5^{a2}	0.03^{*}	5.04^{b2}	5.03^{b2}	5.18^{a2}	5.08^{ab1}	0.02
	Saline(Treat)	5.4^{a1}	4.89^{b1}	4.7^{b1}	4.63^{c1}	0.03^{**}	5.53^{a1}	5.39^{b1}	5.21^{c1}	4.91^{d2}	0.04^{**}
S.E.		0.05**	0.05**	0.05**	0.06**		0.03	0.03*	0.04*	0.06**	
Mg (mg/dl)	Tap(Ctrl)	1.40^{ab1}	1.49^{a2}	1.41^{b2}	1.42^{ab2}	0.01	1.35^{b1}	1.36^{b1}	1.48^{a1}	1.4^{b2}	0.01
	Saline(Treat)	1.50^{a1}	1.60^{a1}	1.63^{a1}	1.59^{a1}	0.02	1.38^{a1}	1.79^{a1}	1.46^{a1}	1.48^{a1}	0.08
S.E.		0.03	0.02*	0.03**	0.03**		0.02	0.16	0.02	0.02**	

^{a,b,c,d} Within the season, mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

^{1,2} Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error.

* $p<0.01$.

** $p<0.001$.

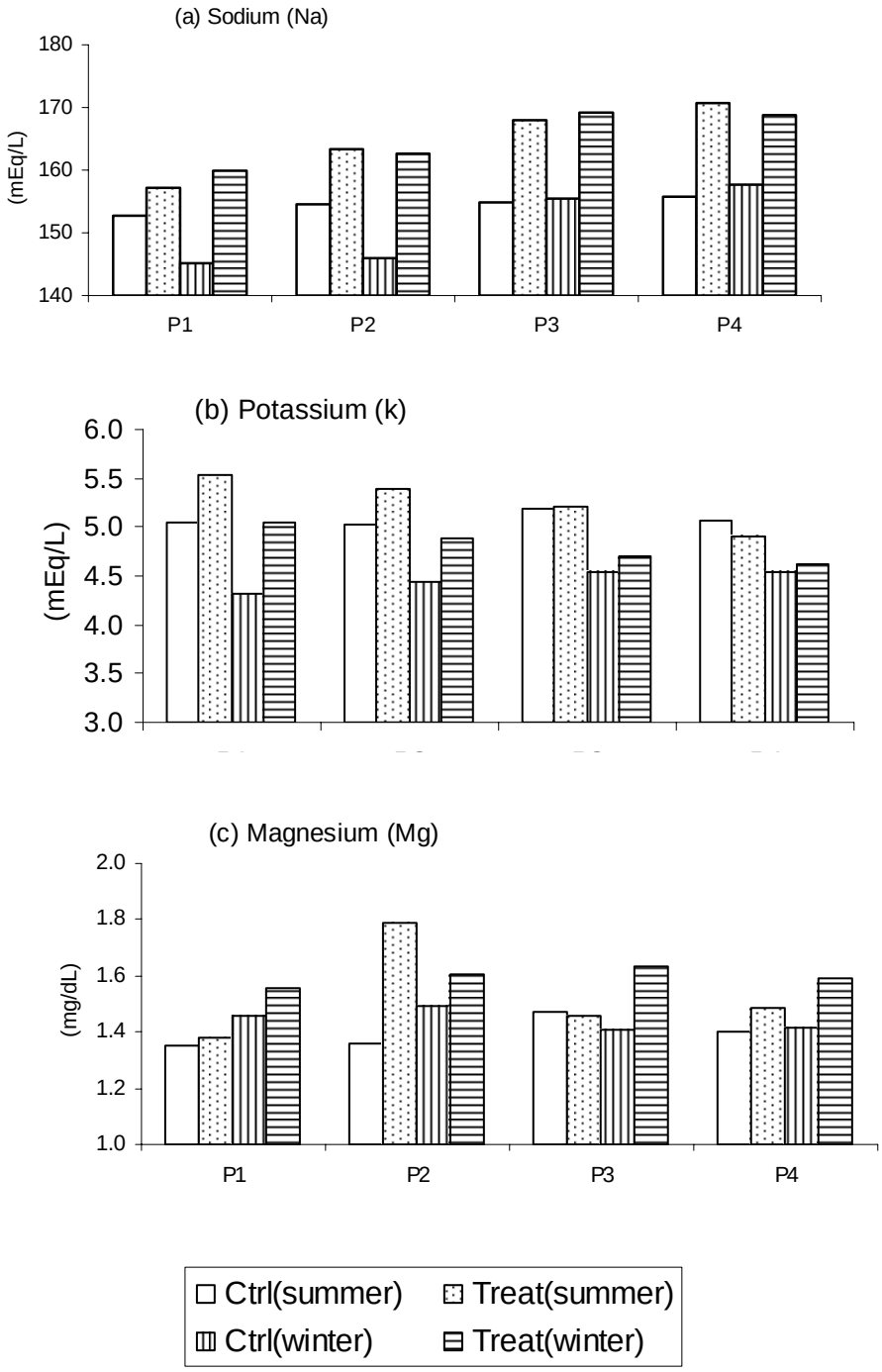


Fig. 22 Effects of salinity of drinking water and season on serum sodium, potassium and magnesium concentrations.

3.3.11 Urine electrolytes and urea

Table 9 shows the effects of salinity of drinking water and season on urine electrolyte and urea concentrations. In both seasons, urine urea and Mg concentration increased significantly by drinking saline water compared with the control group values, except for the Mg level at P1 and P2 in winter (Fig. 24 a,b). Similarly, the urine Na concentrations during winter were significantly higher ($p<0.001$) in treated groups than the control group values. However, the K concentration was not affected by drinking saline water except during P4 in winter and P3 in summer only (Fig. 23 b).

Table 9: The effects of salinity of drinking water on urine electrolyte and urea of Nubian goats during winter and summer.

Parameters	Water type	Winter					Summer				
		Experimental period				S.E.	Experimental period				S.E.
		P1	P2	P3	P4		P1	P2	P3	P4	
Na (mEq/L)	Tap(Ctrl)	179.2^{b2}	180.8^{ab2}	183.1^{ab2}	185.5^{a2}	1.05	168.9^{b1}	173.9^{a1}	173.7^{a1}	175.5^{a1}	0.68^{**}
	Saline(Treat)	193.9^{c1}	195.9^{bc1}	197.1^{ab1}	198.7^{a1}	0.47^{*}	168.6^{d2}	171.8^{c2}	175.4^{b1}	179.4^{a1}	0.77^{**}
S.E.		1.85**	1.87**	1.79**	1.82**		0.66	0.53	0.6	1.16	
K (mEq/L)	Tap(Ctrl)	6.23^{c1}	6.32^{bc1}	6.5^{ab1}	6.6^{a2}	0.05	5.96^{ab1}	5.93^{b1}	6.08^{a1}	6.03^{ab1}	0.02
	Saline(Treat)	6.27^{c1}	6.32^{c1}	6.68^{b1}	6.8^{2a1}	0.04^{**}	5.8^{a1}	5.75^{a1}	5.91^{a2}	5.98^{a1}	0.04
S.E.		0.06	0.04	0.05	0.05		0.05	0.05	0.04	0.03	
Mg (mg/dl)	Tap(Ctrl)	16.78^{a1}	16.98^{a1}	16.18^{a2}	16.92^{a2}	0.19	14.36^{a2}	14.1^{a2}	14.53^{a2}	14.93^{a2}	0.16
	Saline(Treat)	17.85^{a1}	17.37^{a1}	17.8^{a1}	18.31^{a1}	0.16	15.18^{d1}	16.0^{c1}	16.61^{b1}	17.48^{a1}	0.16^{**}
S.E.		0.35	0.22	0.26**	0.23**		0.19	0.23**	0.30**	0.35**	
Urea (mg/dl)	Tap(Ctrl)	12.97^{a2}	13.82^{a2}	13.63^{a2}	14.06^{a2}	0.24	11.92^{b2}	12.38^{b2}	14.68^{a2}	14.95^{a2}	0.25^{**}
	Saline(Treat)	15.98^{b1}	16.33^{b1}	17.03^{a1}	17.44^{a1}	0.13^{**}	14.03^{c1}	16.13^{b1}	16.53^{ab1}	17.12^{a1}	0.23^{**}
S.E.		0.42**	0.32**	0.44**	0.46**		0.39*	0.43**	0.24**	0.29**	

[a,b,c,d] Within the season, mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

[1,2] Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error. * $p<0.01$. ** $p<0.001$.

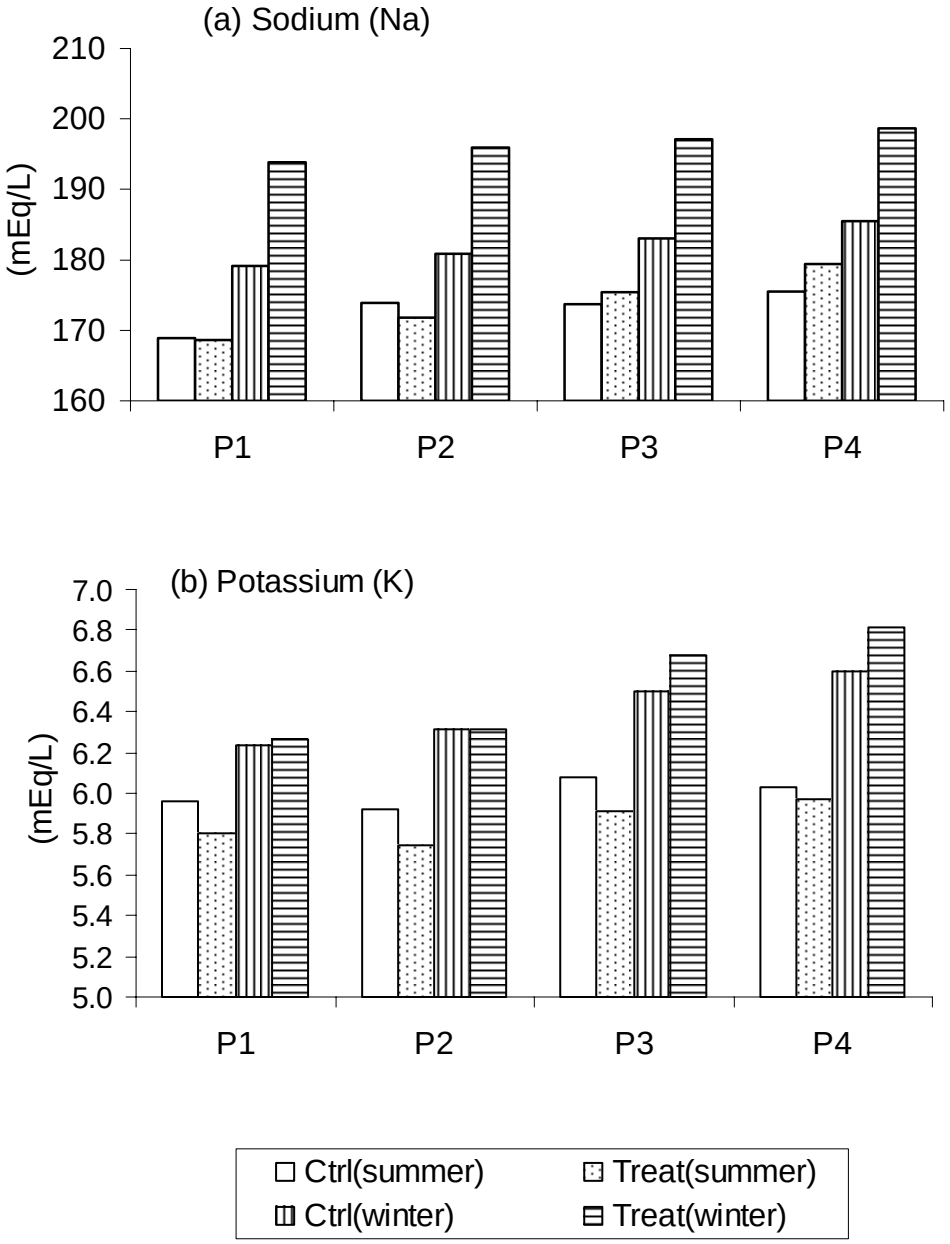


Fig. 23 Effects of salinity of drinking water and season on urine sodium and potassium concentrations.

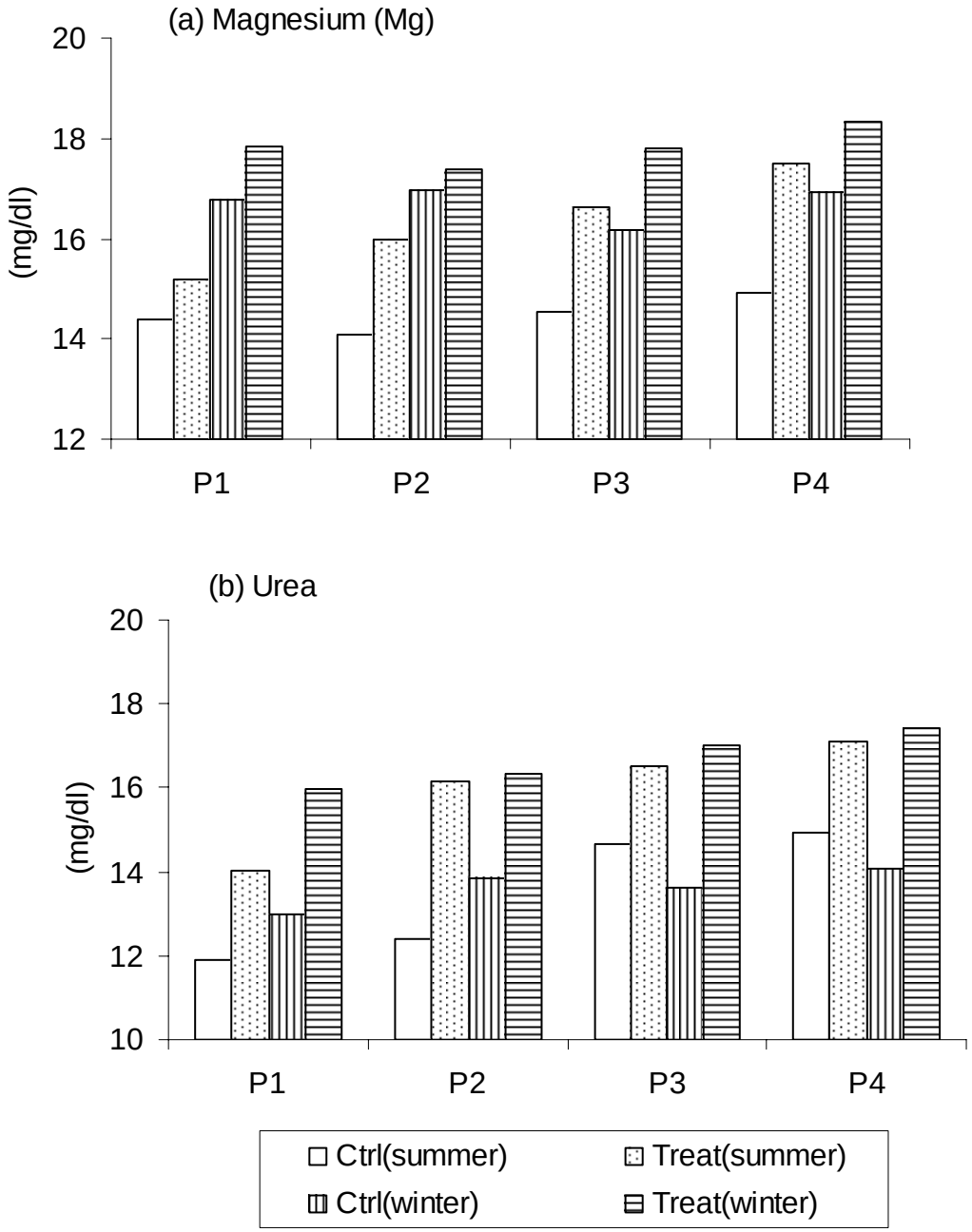


Fig. 24 Effect of salinity of drinking water and season on urine magnesium and urea concentration.

3.4 Discussion

The present study was designed to determine the physiological responses of Nubian goats to increasing the salinity of drinking water during winter and summer.

The changes in rectal temperature (Tr) for the control (tap water) and treated groups (saline water) during the consecutive periods (P1-P4) showed an almost similar pattern (Fig.3 a,b): this indicates that the increase in NaCl concentration in drinking water had no significant effect on Tr. El Gawad (1997) reported that Tr of goats offered saline well water (0.8%) was slightly affected.

There was a direct positive correlation between Tr and ambient temperature (r = +0.84) (Fig. 5). The higher values of Tr of goats measured during summer is clearly attributed to the increase in heat gain from the thermal environment. This result is comparable and in agreement with the findings reported in previous studies by Heisey *et al*. (1971) for goats, Hales and Webster (1967) for sheep, and Abdelatif (1978) for goats and sheep which demonstrated that Tr increased in response to heat exposure.

The increase in Tr of the goats in the afternoon period (Table 3) is attributed to the increase in ambient temperature during the day (Table 2). Also the increase in Tr could be partially attributed to increase in metabolic heat production associated with enhanced muscular activity and metabolism of food (Cyril and Eric, 1971). This result is comparable and in agreement with other studies by Al Hadi *et al*. (1977) and Abdelatif (1978).

The significant increase in body temperature of goats with high ambient temperature during the summer or in the afternoon (2:30 p.m) resulted in a significant increase in respiratory rate (Table 3). Temperature perception is mediated by peripheral thermoreceptors and thermosensitive units in the central nervous system; warming of the pre-optic region of the hypothalamus activates all available physiological and behavioural heat-loss mechanisms. Baker and Nijland (1993) reported that the respiratory evaporative heat loss increased significantly with increase in brain and central blood temperature in exercised goats. Baker (1989) reported that Nubian and Alpine-Toggenberg goats increased evaporation by panting and sweating during heat exposure.

The increase in RR is a normal physiological response to dissipate heat from the body and to reduce hyperthermia as explained earlier by El Hadi *et al*. (1977) and Abdelatif (1978) who noted that the higher body temperature on heat exposure indicates that the heat production and gain from the hot environment exceed the heat loss. In such situations, since goats are unable to sustain high sweat output (Jenkinson, 1972), the available avenue through which the surplus heat can be lost is by respiratory evaporative cooling. However, Yeates (1965) pointed out that cooling by respiratory evaporation is relatively inefficient when compared to sweating because of the increased physical exertion of faster breathing and the resultant heat generation, but Baker (1982) and Robertshaw and Dmi'el (1983) reported that panting serves two purposes; First, panting involves no losses of salt and thereby blood plasma volume is better preserved. Second, panting involves cooling of the blood passing the nasal area, which makes it

possible to keep brain temperature lower than deep body temperature, this is important since the dehydrated goat can not prevent its deep body temperature to rise.

In the present study, the higher values of RR recorded for goats receiving saline water during summer at 2:30 p.m compared to the control group (Table 3) may be attributed to the high intake of NaCl associated with high consumption of saline water. Assad and Elsherif (2002) reported that salinity decreases the animals' efficiency of thermoregulation under hot conditions. Salinity decreased the blood volume, plasma volume, and interstitial fluids which play an important role in coping with heat stress by evaporation (Assad and Elsherif, 2002). El Gawad (1997) reported that RR increased in goats drinking saline well water (0.8% TSS).

In both seasons, the water intake (ml/day) by treated groups was higher than the respective control group values during the experimental periods (Table 4). An increase in NaCl concentration from 0.8 to 1.6% increased water consumption by the goats significantly. This increase may be related to stimulation of the hypothalamic region which is affected by Na concentration in the extracellular fluid and the plasma osmolality. Thornton *et al*., (1985) reported that intracarotid infusion of hypertonic solutions in conscious goats produced a significant increase in osmolality and increase in sodium concentration of the cerebrospinal fluid and increase in blood osmolality followed by increase in water intake. Houpt (2004) indicated that when hypertonic NaCl solution is administered intravenously in sheep, water will begin to shift into the plasma and increased osmolality of the extracellular fluid (ECF) would cause cellular dehydration.

When the body fluid volume is reduced or the osmolality of the extracellular fluid increases, cells in the hypothalamus react to induce increased secretion of vasopressin and thirst (Andersson, 1953). These cells mainly respond to changes in sodium concentration of the cerebrospinal fluid, but also other somotically active substances, applied from the blood side of the blood-brain-barrier, can stimulate release of vasopressin and thirst (Andersson and Olsson, 1973; McKinley *et al*., 1978). Centrally produced angiotensin I or angiotensin II from the periphery acting on the circumventricular organs in the brain, act in consort with the sodium ion in the regulation of water balance (Blair-West *et al*., 1994). Recently, a population of neurons in the hypothalamus, which are preferentially activated by intravenous infusions of hypertonic saline or angiotensin II, have been identified. They are probably the postulated sodium-osmoreceptors (Oldfield *et al*., 1994). An increase in water intake related to saline water drinking has been reported by Abou Hussien *et al.* (1994) and El Gawad (1997) in goats and Meintjes *et al*. (2004) in sheep.

In the present study, in both seasons, the water intake by goats decreased as NaCl concentration in drinking water was inhanced from 1.6 to 2% NaCl (Table 4). This indicates that goats can tolerate 1.6% NaCl but when the concentration was increased to 2%, it reduced the effect of saline load by reducing the amount of water intake. Assad and El sherif (2002) suggested that camels protected themselves from salt stress by lowering the amount of saline water intake. Underwood *et al*. (1999) reported that higher salt intakes are tolerated when added to the diet if pure water is freely available, because the animal can compensate to some degree by increasing

its intake of fresh water, thereby increasing the salt-excecretion capacity of the kidneys; but when the water is itself rich in salt, the animal is unable to adapt in this way. The reduction of water intake also may be partly attributed to the taste. Bell (1959) attributed the rejection of saline drinking water by dairy goats to the taste responses.

The tolerance of animals to salinty of drinking water is different due to species, environment and adaptation. Peirce (1957, 1965) reported that sheep tolerated water containing 1.3% NaCl, but with 2% NaCl, feed consumption and body weight declined and some animals became weak and emaciated. Studies on cattle showed that the animals on 2% NaCl in drinking water drank less than those on 1% NaCl (Weeth *et al*., 1960). At high environmental temperatures and dry conditions, the tolerable salt concentration is reduced, because of increase in water consumption (Settle *et al*., 1999). In the present study, the lower values of food consumption by the goats related to the effect of high salinity of drinking water (2% NaCl) obtained only during summer (Table 5). McGregor (2004) reviewed that goats can tolerate high salinity levels, but they need to be adapted to saline water.

The significant increase in water intake of Nubian goats during summer (Fig 7) is attributed to using more water for heat dissipation from the body and to reduce hyperthermia by evaporative cooling. The increase of water intake in response to increase ambient temperature is in agreement with the findings reported by Maloiy and Taylor (1971) and Adogla-Bessa and Aganga (2000) for goats and Sanchez and Evans (1972) for sheep and Abdelatif (1978) for goats and sheep.

In the present study, in both seasons, high concentrations of NaCl (1.6 and 2%) in the drinking water resulted in a significant decrease in food intake of the goats (Table 5). This decrease may be attributed to the effect of saline water on the rumen micro flora and saliva secretion. Feed intake during a meal can be limited by the rise in osmolality of ruminal fluid, which is sensed in the wale of the rumino-reticulum. Phillips *et al*. (1981) observed a linear decrease in food intake associated with an increase in the osmolality of ruminal fluid as a result of ruminal infusions of NaCl solutions. Richard *et al*. (1990) reported that the tonicity of plasma increases toward the end of a large meal as a consequence primarily of absorption of VFA and Na from the rumen and fluid shifts into the gut. This hypertonicity is sensed centrally to inhibit parotid secretion by a reduction in the parasympathetic stimulation to the gland. Decreases in the flow rate of both parotid and total saliva have been reported in sheep following intravenous infusions of hypertonic solutions (Warner and Stacy, 1977). An adverse effect on the rumen flora could have retarded digestion of the food, with decreased rate of its passage through the alimentary tract, and consequently it reduced food consumption. Peirce (1957, 1963) reported that drinking water containing 1% NaCl had no adverse effect on Merino sheep, but 1.5% was detrimental to a small proportion and 2% was detrimental to all of the sheep. Wilson (1966) reported that the food intake of sheep declined at the higher concentrations of NaCl (10-20% in food, 1.5-2.0% in water). In studies on cattle, hay consumption of the animals offered 1% NaCl in drinking water was slightly less than that of those on tap water, and hay consumption of animals offered 2% NaCl was very low (Weeth *et al.*, 1960).

Wilson (1965) reported that intake of Atriplex (salt bush) by sheep decreased to less than half when the drinking water was replaced by water containing 0.9 or 1.2% NaCl. He concluded that in sheep dependent entirely on salt bush, the drinking water should contain not more than 0.6% NaCl. The sheep with a choice of high and low salt rations can partly avoid the stress of saline drinking water or restricted water supply by changing the proportion of each ration eaten (Wilson, 1968).

The increase in water to feed ratio in treated groups compared with control groups of goats in the present study (Table 5) is attributed to the increase in water consumption on one hand and the decrease in food intake on the other hand for treated groups.

The results indicate that the mean body weight gain was significantly lower in the group of goats receiving 1.6% NaCl during winter (Table 5). This result could be related partially to the reported reduction in food intake with 1.6% NaCl in drinking water during winter. Peirce (1957) reported that the changes in body weight of animals are presumably the direct consequence of changes in food consumption. Peirce (1957, 1963) and Wilson (1966) reported that a concentration of 1% sodium chloride in the drinking water had no adverse effects on the body weight of sheep, but there was a decline in body weight of several animals receiving 2% NaCl in drinking water. El Gawad (1997) found that the body weight was not affected in the goats offered moderate saline of well water (0.8 % TSS) for 6 weeks.

Studies on heifers showed that the growth rate as indicated by body weight was not affected by drinking 1% NaCl in drinking water; heifers on

1% salt water lost slightly more weight than those on tap water and heifers on 2 % salt water lost more weight during the first 10 days (Weeth *et al.*, 1960). However, studies on West African dwarf kids showed that optimum changes in body weight and development occurred with sodium supplementation of between 0.4 and 0.5% in the drinking water (Ogebe *et al*., 1995). Theses differences may be attributed to the factors as a type of goats, age, body weight and NaCl concentration.

The importances of dietary mineral supplementation on overall production have been studied. Miles and McDowell (1983) reported that mineral supplementation dramatically increased all production parameters. Hagsten *et al*. (1975) and Morris and Peterson (1975) reported that the minimum sodium requirement of lambs for satisfactory growth and of lactating ewes for maintenance of body weight and milk production were 1.0 g and 0.8 g Na/kg DM, respectively. McDowell *et al*. (1993) reported weight losses due to NaCl deficiency resulting from lack of appetite.

In the current study, the decrease in body weight with increase in salinity of drinking water was significant only during winter (Table 5). This observation could be attributed to the use of nutrients for heat production. Stefan *et al.* (1977) reported that cooling the anterior hypothalamus increased heat production. A depletion of skeletal muscle because of the higher demand for energy occurs during exposure to the cold environment (Andersson and Jonasson, 1993).

The current results also indicate that the highest values of body weight gains were recorded during summer at P2 for the control as well as treated

group. This observation could be attributed partially to the reported increase in water and food intake (Table 4 and 5).

The current results indicate that the Packed Cell Volume (PCV) and haemoglobin concentration (Hb) were influence significantly by water and food consumption related to saline load and seasonal changes. There was a marked decrease in the PCV and Hb concentration for the groups receiving 1.2 and 1.6% NaCl in drinking water compared to respective control group values during summer (Table 6), however, this decline reach the significance level for the PCV only. The observed decline in PCV may be partially attributed to haemodilution which occurred as a result of the increase in water consumption during summer (Table 6). Also this decline may be attributed to the decrease in food intake by the group receiving saline water during summer (Table 5). Swenson (2004) reported that nutritional status, blood volume and environmental temperature may affect PCV and Hb concentration in animals. In winter, the highest values of haemoglobin concentration (Hb) and PCV for treated groups were recorded during P4 (2% NaCl). This may be attributed to haemoconcentration associated with decrease in water intake due to the increase in NaCl concentration in the drinking water particularly during winter.

In the present study, the plasma glucose level was not affected significantly by gradual increase in salinity of drinking water during summer (Table 6). Also during winter, the changes in plasma glucose level for the control (tap water) and treated groups (saline water) during the consecutive periods (P1-P4) had similar trends (Fig. 19). This indicates that increasing NaCl concentration had no significant influence. The stability of plasma

glucose level in the present study could be related to the fact that the depressive effect of reduction in food intake has been couterbalanced by the effect of haemoconcentration. Assad and Elsherif (2002) reported that, blood volume, plasma volume, extracellular fluids and interstitial fluids decreased by increasing NaCl concentration for ewes. Furthermore, the decrease in plasma glucose level could be related to the fact that increase in salinity of drinking water was associated with decrease in food intake.

In the present study, the mean plasma glucose level for control as well as treated groups was slightly higher during winter compared to values obtained in summer. This result could be related to the increased thyroid activity in winter. Young (1976) reported that cold exposure increased thyroid function in sheep. Hugo (2004) reported that the excess of T_3 and T_4 increase metabolic rate of substances by increase O_2 consumption. The metabolism of carbohydrate increased the glucose level in the blood (Donald, 2004).

In the present study, the serum concentrations of total protein (Tp) and albumin (Alb) were not affected significantly by gradual increase in salinity of drinking water during summer (Table 7). This result could be related to the fact that the haemodilution that occurred as a result of increased water consumption by the goats has been counterbalanced by the effect of haemoconcentration that resulted from increase in evaporative water loss during summer. However, during winter, Tp and Alb concentrations increased significantly by gradual increase in salinity of drinking water. The higher serum concentration of Tp and Alb may be related to the role of Na in

absorption of amino acids from the gut and subsequent utilization of the amino acids in the formation of plasma proteins (Ganong, 2003).

The results showed a significant decrease in serum urea level for the groups receiving high concentrations of NaCl in the drinking water compared to the other experimental groups during both seasons (Table 7). This may be attributed to an increase in glomular filtration rate (GFR). Godwin and Williams (1986) and Meintjes *et al*. (2004) reported that the GFR was a significantly higher in goats receiving high concentrations of NaCl compared to others receiving tap water and low concentrations of NaCl. This had the effect of making relatively much urea available to the nephron tubule with high concentrations of NaCl in the drinking water compared to low concentrations of NaCl in the drinking water. Also it could be attributed to an increase of urea delivery to the rumen. Meintjes and Engelbrecht (2004) reported that the delivery of urea to the rumen is enhanced by the intake of saline drinking water, and that this may have an effect on plasma urea concentrations, or possibly under conditions of excess salt intake, the kidney adjusts the ratio of urea to sodium in the medullary interstitium in favour of the former. The present results in goats are in agreement with the findings of Weeth *et al*. (1960) in heifers and Meintjes and Engelbrecht (2004) in sheep.

The current results indicate that in both seasons and for all saline water drinking groups there was a significant increase in serum concentrations of Na compared to the respective values obtained for the control group (Table 8). Excess of sodium is mainly excreted by the kidneys. The increase in plasma sodium concentration stimulates vasopressin

secretion and thirst which leads to increase in plasma volume. Hypernatraemic hypervolaemia increases the glomerular filtration rate, the aldosterone secretion falls and the reabsorption of sodium in the kidneys and gut decreases to a minimum eliminating the extra sodium (Holtenius and Dahlborn, 1990).

The increase in serum Na concentration in goats consuming saline water may also be associated with increase in NaCl intake through the drinking water. Heller and Paul (1934) reported increase of approximately 10% in the concentrations of sodium and chloride in the blood of sheep which received water containing 2.0% NaCl. Also Constable *et al*. (1991) reported that the hypertonic saline solution (2.4% NaCl) infused intravenously to calves induced a significant increase in serum Na and Cl concentrations associated with an increase in serum osmolality.

In the present study, during winter, the changes of Na serum concentrations for the control (tape water) and treated groups (saline water) during the consecutive periods (P1-P4) had a similar pattern (Fig.22a). This indicates that to increasing NaCl concentration did not influence. However, during summer, there was a significant increase in soduim serum concentration with increase in the concentration of NaCl in drinking water. This may be attributed to haemoconcentration that occurred with higher intake of saline water by goats reported during summer. Haemoconcentration with increase in NaCl concentration in drinking water was previously reported by Weeth *et al*. (1960) in cattle and Assad *et al*. (2002) in sheep.

The serum K level decreased significantly with increasing the salinity drinking water in both season (Table 8). This decline may be attributed to the effect of salinity of drinking water on renal function. Potter (1968) found an increase in K excretion during acute Na loading in sheep adapted to either rain water or salt water drinking. Also Wesson (1969) reported that the renal excretion of K by man and dogs increased by an increase in Na load. Moreover, the increase in excretion of water with saline drinking could be associated with an increase in urinary excretion of K. Previous studies have reported an increase in urinary volume and electrolytes excretion during saline water drinking in sheep (Potter, 1963) and cattle (Weeth and Leperance, 1965).

In the present study, the serum concentration of Mg was not affected by gradual increase in the concentration of NaCl in drinking water (Table 8). This finding is in agreement with Peirce (1957, 1960, and 1963) who found no influence of saline drinking water on plasma magnesium concentration.

In the current studies, in both seasons there was a significant increase in urine urea level with increasing NaCl concentration in the drinking water (Table 9). Also in both season, the urine urea values for treated groups were signifacntly higher compared to respective control group values. The significantly greater GFR for goats receiving high concentrations of NaCl compared to others which receiving tape water and low concentrations of NaCl makes as much urea available to the nephron tubule. Abou Husien *et al.* (1994) concluded that sheep and goats control salt load while drinking saline water by excreting more urine and increasing the GFR in order to reduce the high salt load resulting from high consumption of saline water

and the excretion of urea was higher for goats receiving high concentrations of NaCl compared to others receiving tap water and low concentrations of NaCl. The present result in agreement with finding reported by Godwin and Williams (1986) and Meintjes, *et al* (2004) for sheep.

The results indicate that in both seasons there was a significant increase in urine Na concentration with increase in the concentration of NaCl in the drinking water (Table 9). This observation could be related to increase GFR and excretion of Na. This result is comparaple with the findings reported in studies by Potter (1968) who indicated that in sheep drinking saline water caused an increase in both GFR and excretion of Na, and with the finding of Godwin and Williams (1986). Furthermore, Meintjes and Engelbrecht (2004) reported that during the phases of salt loading, natriuresis was obligatory for homeostasis. There was also a need to excrete the excess water taken in when saline water was the only source of drinking water available. Accordingly, the fractional excretion of sodium rose significantly with increasing NaCl level. As atrial natriuretic peptide (ANP) has a potent effect on increasing the fractional excretion of Na (Sonnenburg, 1990), it is highly likely that plasma concentrations of this hormone were also raised and accounted for the increases in the fractional excretion of Na seen in the present study.

The urine K and Mg levels increased with increasing salinity of drinking water (Table 9). This increase may be attributed to increase in water excretion by the effect of salinity of drinking water. Previous studies have reported an increase in electrolytes excretion during saline water drinking in sheep (Potter, 1963) and in cattle (Weeth and Leperance, 1965).

Potter (1968) found increased K excretion during acute Na loading in sheep adapted to either rainwater or salt water drinking. Also Wesson (1969) reported that the renal excretion of K by man and dogs increased by an increase in Na load.

3.5 Summary

(1) The effects of salinity of drinking water (0.8, 1.2, 1.6 and 2% NaCl) on thermoregulation, water and food intake and blood and urine composition have been investigated in Nubian goats during summer and winter.

(2) The rectal temperature (Tr) was not affected by salinity of drinking water. With all experimental groups of animals Tr values were higher during summer.

(3) The respiration rate (RR) during summer at 2:30 p.m, was significantly higher with all groups receiving saline water compared to respective groups receiving tap water. The RR values were higher during summer than winter.

(4) In both seasons, the values of Tr and RR obtained at 2:30 p.m were significantly higher than the values recorded at 8:30 a.m.

(5) In both seasons, water intake (ml/day) by treated groups was significantly higher compared to respective control group values. The increase in NaCl concentration from 0.8 to 1.6% NaCl in drinking water increased water consumption by the goats but at 2% NaCl, water intake decreased in both seasons.

(6) The intake of NaCl in drinking saline water increased significantly with increase in NaCl concentration in the drinking water.

(7) In both seasons, high concentrations of NaCl (1.6 and 2%) in the drinking water resulted in a significant decrease in food intake of the goats.

(8) The mean body weight change was significantly lower in the group receiving 1.6% NaCl during winter compared to respective control group.

(9) The packed cell volume (PCV) level during summer was significantly lower for groups receiving 1.2 and 1.6% NaCl in drinking water compared to respective groups offered tap water. The highest value of PCV for treated groups was recorded during winter in the group offered 2% NaCl in the drinking water.

(10) The highest values of Hb for treated groups were recorded during winter in the group offered 2% NaCl in the drinking water.

(11) The plasma glucose level was not affected by salinity of drinking water in both seasons. The mean plasma glucose level for control as well as treated groups was slightly higher during winter compared to values obtained in summer.

(12) The serum total protein (Tp) and albumin (Alb) concentrations increased significantly by gradual increase in NaCl concentrations in drinking water during winter. In both seasons, Tp and Alb were higher for the groups offered 1.2, 1.6 and 2% NaCl compared to respective control groups.

(13) In both seasons, the serum urea level was significantly lower in the groups receiving high concentrations of NaCl (1.6 and 2%) in the drinking water compared to the lower concentrations.

(14) In both seasons, the serum concentrations of Na were significantly higher in all groups offered saline water compared to the respective control groups. The increase in NaCl concentration in the drinking water increased the serum Na level significantly during summer.

(15) The serum potassium (K) level in both seasons decreased significantly with increasing NaCl concentration in the drinking water.

(16) In both seasons, the serum magnesium (Mg) level was not affected by gradual increase in the concentration of NaCl in drinking water.

(17) In both seasons, there was a significant increase in urine urea level with increasing NaCl concentration in the drinking water. The urine urea values in both seasons were significantly higher in treated groups compared to respective control groups.

(18) In both seasons, there was a significant increase in urine Na concentration with increasing NaCl concentration in the drinking water. The urine Na values were higher signifacntly in treated groups compared to respective control groups during winter.

(19) The urine K level was increased significantly with increasing NaCl concentration in the drinking water during winter.

(20) The urine Mg levels in both seasons were higher in treated groups compared to respective control groups. There was a significant increase

in urine Mg concentration with increasing NaCl concentration in the drinking water during summer.

CHAPTER FOUR

THE EFFECTS OF SALINE WATER DRINKING, DEHYDRATION AND REHYDRATION ON THERMOREGULATION AND BLOOD COMPOSITION OF NUBIAN GOATS DURING WET SUMMER

4.1 Introduction

Most livestock have to drink at least every other day to be productive, and every few days to survive. The provision of water is therefore of prime importance in all animal production systems. Limited water availability is a major factor influencing the productivity of ruminants in desert and tropical regions (Shkolink and Silanikove, 1991).

When water intake is restricted, dehydration may occur. Animals attempt to conserve water by producing concentrated urine, faeces and reducing evaporative water loss. Ahmed and El Kheir (2004) reported that dehydrated goats decreased water turnover rate and evaporative losses.

Water intake is known to influence feed intake and digestibility (Aganga, 2000). Restriction of voluntary feed intake is the first response to restriction of water intake in humans (Engell, 1988) and various animal species including goats (Adogla-Bessa and aganga, 2000), cattle (Martine *et al*., 2001) and camels (Ben Goumi, 1993). Ruminants differ from monogastric animals because much more saliva is secreted during eating and because they have a large fluid reserve in the rumen, which can buffer osmotic changes in the rumen derived from digesta (Martine *et al*., 2001). In previous studies, pygmy goats (Langhans *et al*., 1991) progressively reduced food intake during water deprivation and did not compensate for the

dehydration-induced weight loss by increasing food intake during the subsequent rehydration period. Water deprivation causes a marked decrease in body weight in goats (Adogla-Bessa and Aganga, 2000; Ahmed and Ammar, 2001; Ahmed and El kheir, 2004), sheep (Abdelatif and Ahmed., 1994), cattle (Martine *et al*., 2001) and camels (Ben Goumi, *et al*., 1993).

In dehydrated animals, the changes which occur in the blood constituents are modulated mainly by haemoconcentration (Abdelatif, 1978). Dehydration in goats causes increase in packed cell volume (PCV) and haemoglobin (Hb) concentration (Ghosh, 1983; Adogla-Bessa and Aganga, 2000), total protein and Na concentrations (Hossaini-Hilali *et al*., 1994) and urea (Aganga *et al*., 1988).

On the other hand, water deprivation was found to improve the digestion and utilization of feed and enhance nitrogen utilization in poorly nourished small ruminants (Mousa and Elkalifa, 1992; Kaushish and Mittal, 1994).

Breeds of ruminant which are well adapted to a desert environment demonstrate a greater capability to ameliorate the stressful effects induced by water deprivation (Maltz *et al*., 1984 ; Silanikove, 2000) and therefore maintain higher feed intake and productivity than non desert breeds (Ferreira *et al*., 2002). There are differences between breeds of goats in their ability to resist dehydration based on genetics and environmental history. Greenwald (1967) found that desert Hottentot goats from South Africa were more resistant to dehydration with lower water consumption, evaporative and urinary losses compared with Swiss-type milk goats.

Several researchers have studied the effect of dehydration on physiological, biochemical and behavioral mechanisms for goats (Langhans *et al*., 1991; Qinisa, and Boomker, 1999; Aganga, 88, 92, 2000; Misra and Khub, 2002), sheep (Aganga, 1992; Michell, and Moss, 1995), cattle (Martine *et al*., 2001) and camels (Ben-Goumi *et al*., 1993).

The situation is further complicated during the long dry season by the high salinity of drinking water obtained from wells (Atwa, 1979) and salt herbage (Wilson, 1966). Previous studies showed that Goats prefer saline water with about 1.2% NaCl compared with fresh water (Bell, 1959; McGergor, 2003). Peirce (1957, 1965) reported that sheep tolerated water containing 1.3% NaCl.

The information reported indicates the influence of dehydration and salinity of drinking water on the physiological responses of animals. However, there are no published reports on the combined effects of drinking saline water and water deprivation in adult goats under tropical conditions. The objective of this experiment was to investigate the combined effects of 1.2% NaCl in drinking water and dehydration on physiological responses of Nubian goats.

4.2 Experimental plan

A total number of six Nubian goats were used in this experiment. The animals were randomly assigned to two groups, control and treated, of three animals each. The control group was offered tap water, while the other group was offered tap water supplemented by 1.2% NaCl. The small proportion of sodium chloride usually present in tap water was disregarded. The animals were allowed ad libitum food and water for 10 days, then the animals were dehydrated for 2 days and rehydrated for 4 days. Rectal temperature (Tr) and respiratory rate (RR) were measured daily at 8:30 a.m and 2:30 p.m. The amount of feed and water consumed were recorded every morning before fresh feed and water were offered except that during the dehydration period no water was offered. The measurements of feed and water intake were performed as explained in Chapter 2. Blood samples were drawn from the jugular vein on days 0, 6, 10, after day 1 and day 2 of dehydration then after day 2 and day 4 of rehydration at 10:00 a.m. The samples were used for measurements of PCV, plasma glucose level and serum total protein, albumin, urea, Na, K and Mg are the same of the methods in experimental one. Animals were weighed in the first and last day of the experimental period.

Minimum and maximum ambient temperature (Ta) and relative humidity (RH) were obtained from the Meteorological Station located about 800 m from experimental site.

4.3 Results

The data obtained in this experiment were subjected to statistical analysis. The values reported in Tables are mean values ± standard deviation. In the diagrams, the abbreviations Normal, De and Re indicate normal hydration, dehydration and rehydration period, respectively. ctrl and treat indicate control group (tap water) and treated group (saline water), respectively.

4.3.1 Climatic measurements

The minimum and maximum ambient temperature (Ta) and relative humidity (RH) for the experimental period are shown in Table 10. The data indicated that the ambient temperature (Ta) was relatively steady, the mean values of Ta ranged between 29.3 and 34.8 ˚C. The relative humidity (Rh) values ranged between 18 and 26%.

4.3.2 Rectal temperature (Tr) and respiration rate (RR)

Table 11 shows the effect of salinity of drinking water and hydration level on rectal temperature (Tr) and respiration rate (RR) during wet summer.

In the morning (8:30 a.m.) rectal temperature (Tr) of the treated group increased significantly ($p<0.001$) during the dehydration above the normal hydration value; remained high on the following days of rehydration, and then decreased on the fourth day of rehydration. There was no significant difference between the values of control group compared to the respective

Table 9: The minimum and maximum ambient temperature (Ta) and mean relative humidity (RH) during the experimental period in wet summer (August, 2002).

Days	Ta(ºC)			RH (%)
	Min	Max	Mean	
1	27.5	42.0	34.75	22
2	25.5	38.0	31.75	18
3	23.0	38.0	30.5	20
4	24.5	38.0	31.25	22
5	24.5	38.0	31.25	20
6	24.5	38.5	31.5	24
7	26.0	39.8	32.9	24
8	26.6	39.6	33.1	20
9	27.0	38.0	32.5	30
10	26.0	39.0	32.5	29
11	26.5	38.5	32.5	31
12	23.5	39.5	31.5	26
13	25.5	40.6	33.05	28
14	27.0	40.0	33.5	31
15	23.5	36.8	30.15	27
16	24.5	34.0	29.25	26

treated group values except on the second and the fourth day of rehydration period where the treated group values were significantly higher than the control group values. The afternoon (2:30 p.m) values of Tr of treated group tended to be higher during the dehydration than normal hydration values, but this difference attained the level of significance ($p<0.05$) only on the second day of dehydration, and then returned to the normal hydration level on the second day of rehydration (Fig. 25). The afternoon values of Tr of treated group were significantly higher only during the second day of dehydration and the first and the second day of rehydration compared with respective control group values.

The respiration rate (RR) values of both groups increased significantly during the first day of dehydration and then decreased significantly within day 2 of dehydration (Table 11). However, the difference between the normal hydration and dehydration values of RR of the treated group was not significant. On rehydration, the morning and afternoon RR values for the treated group returned to the normal value during the first and second day of the rehydration period. There was no significant difference between RR values of treated group compared to the respective control group values in all of the experiment phases. In both groups, the values of Tr and RR measured at 2:30 p.m were significantly higher ($p< 0.001$) than those obtained at 8:30 a.m (Figure 26).

Table 11: The effects of drinking saline water, dehydration and rehydration on rectal temperature (Tr) and respiration rate (RR) of Nubian goats during wet summer.

(n = 3, mean ± SE.M.)

Parameter	Water type	Normal	Dehydration(days)		Rehydration (days)				S.E.
			1	2	1	2	3	4	
Tr(ºC) at 8:30 a.m	Tap (Ctrl)	37.93^{a1}	38.3^{a1}	38.37^{a1}	38.27^{a1}	38.17^{a2}	38.37^{a1}	37.9^{a2}	0.06
	Saline(Treat)	37.92^{b1}	38.47^{a1}	38.33^{a1}	38.33^{a1}	38.56^{a1}	38.27^{a1}	37.53^{c1}	0.08^{**}
S.E.		0.06	0.11	0.09	0.06	0.11*	0.09	0.13	
Tr(ºC) at 2:30 p.m	Tap(Ctrl)	38.8^{a1}	38.87^{a1}	38.7^{a2}	38.7^{a2}	38.57^{a2}	38.8^{a1}	38.77^{a1}	0.05
	Saline(Treat)	38.95^{b1}	39.17^{ab1}	39.43^{a1}	39.13^{ab1}	38.97^{b1}	38.87^{b1}	38.8^{b1}	0.06
S.E.		0.09	0.14	0.20	0.11	0.11	0.07	0.07	
RR(min^{-1}) at 8:30 a.m	Tap (Ctrl)	25.3^{b1}	38.7^{a1}	28.0^{b1}	28.0^{b1}	28.0^{b1}	26.7^{b1}	22.7^{b1}	1.33
	Saline(Treat)	29.2^{abc1}	34.7^{a1}	24.0^{c1}	28.0^{abc1}	30.7^{abc1}	32.0^{ab1}	25.3^{bc1}	1.0
S.E.		1.08	1.91	1.37	1.03	2.23	2.46	1.03	
RR (min^{-1}) at 2:30 p.m	Tap (Ctrl)	42.0^{b1}	90.7^{a1}	50.7^{b1}	46.7^{b1}	45.3^{b1}	40.0^{a1}	38.7^{a1}	4.35*
	Saline(Treat)	44.7^{c1}	109^{a1}	76.0^{b1}	53.3^{bc1}	48.0^{c1}	48.0^{c1}	46.7^{c1}	5.61**
S.E.		1.55	11.6	7.11	2.68	3.21	3.43	2.46	

^{a,b,c,d} Mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

^{1,2} Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error; * $p<0.01$; ** $p<0.001$.

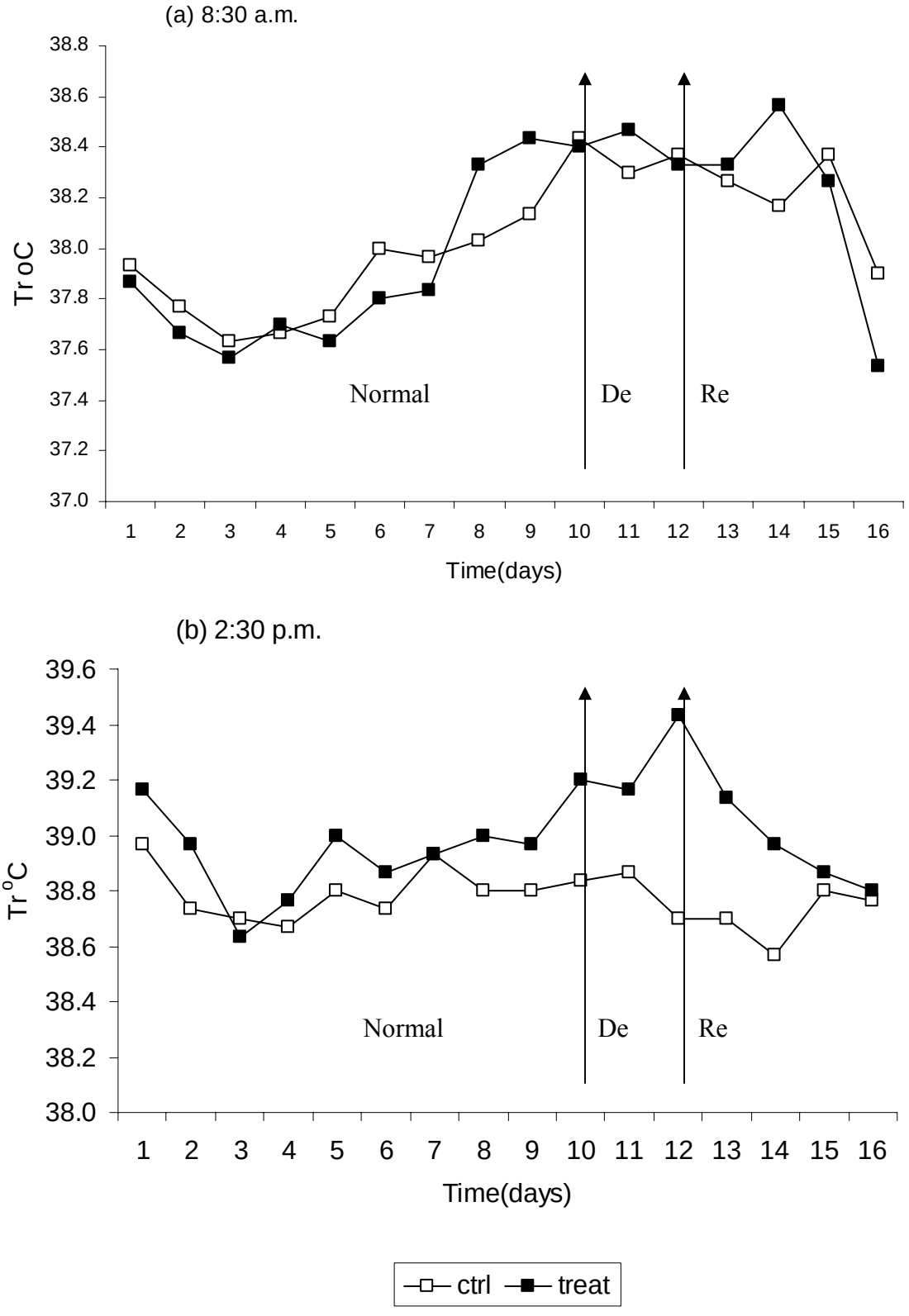


Fig.25 Effects of saline water drinking, dehydration and rehydration on rectal temperature (Tr) of Nubian goats during wet summer.

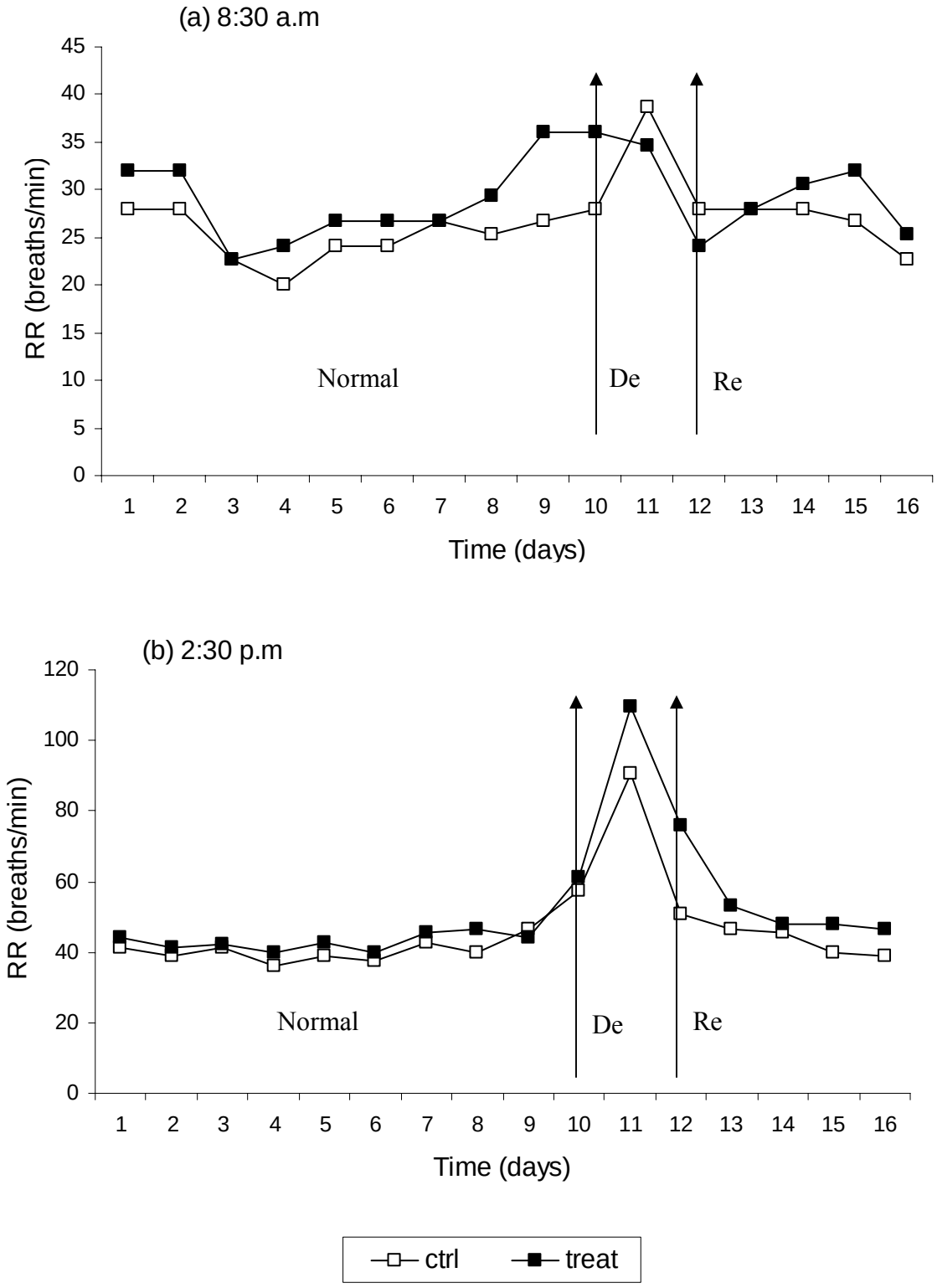


Fig. 26 Effects of saline water drinking, dehydration and rehydration on respiration rate (RR) of Nubian goats during wet summer.

4.3.3 Water intake

Table 12 shows the effect of salinity of drinking water and hydration level on water intake. The water intake (ml/day) by the treated group (1.2% NaCl) was significantly (Table 12) higher than control group values during the period of normal hydration and rehydration except on the second and the third day of rehydration period where there were no difference between the values of control and treated groups. On the first day of rehydration period, water intake increased markedly above the normal hydration level, but the increase was significantly higher in treated group ($p<0.001$) than control group ($p<0.05$). On rehydration the water intake returned to the normal level in days 2 and 3 for the control and treated groups, respectively (Fig. 27).

4.3.4 Sodium chloride intake

The mean daily intakes of sodium chloride from drinking saline water (1.2% NaCl) by the goats, during the normal hydration and rehydration periods are presented in Table 12.

The intake of NaCl (g/day) was related to the consumption of saline water. Thus, there was a highly positive correlation ($r = + 0.99$) between NaCl intake (g/day) and water intake (ml/$kg^{0.75}$) for the treated group as shown in Fig. 28.

Table 12: The effects of drinking saline water, dehydration and rehydration on water intake and sodium chloride intake of Nubian goats during wet summer.
(n = 3, mean ± SE.M.)

Parameter	Water type	Normal	Dehydration(days)		Rehydration (days)				S.E.
			1	2	1	2	3	4	
Water intake(ml/day)	Tap (Ctrl)	3079^{b2}	-	-	6030^{a2}	2767^{b1}	3897^{b1}	2323^{b2}	431
	Saline(Treat)	4755^{b1}			10507^{a1}	2583^{c1}	4503^{b1}	3880^{bc1}	761^{**}
S.E.		389*	-	-	1193	452	357	356**	
Water intake(ml/ $kg^{0.75}$)	Tap(Ctrl)	316.3^{b2}	-	-	615.6^{a1}	288.2^{b1}	396.6^{b1}	239.0^{b2}	43.2^{*}
	Saline(Treat)	449.3^{b1}			995.8^{a1}	247.4^{c1}	425.6^{bc1}	368^{bc1}	72.8^{**}
S.E.		31.2*	-	-	107	49.9	30.0	31.4*	
Sodium chloride intake from saline water (g/day)	Saline(Treat)	57.1^{b1}	-	-	126.1^{a2}	31.0^{c2}	54.0^{b1}	46.6^{bc1}	9.13^{**}

^{a,b,c,d} mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.
^{1,2} mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.
S.E. Standard error.
* $p<0.01$.
** $p<0.001$.

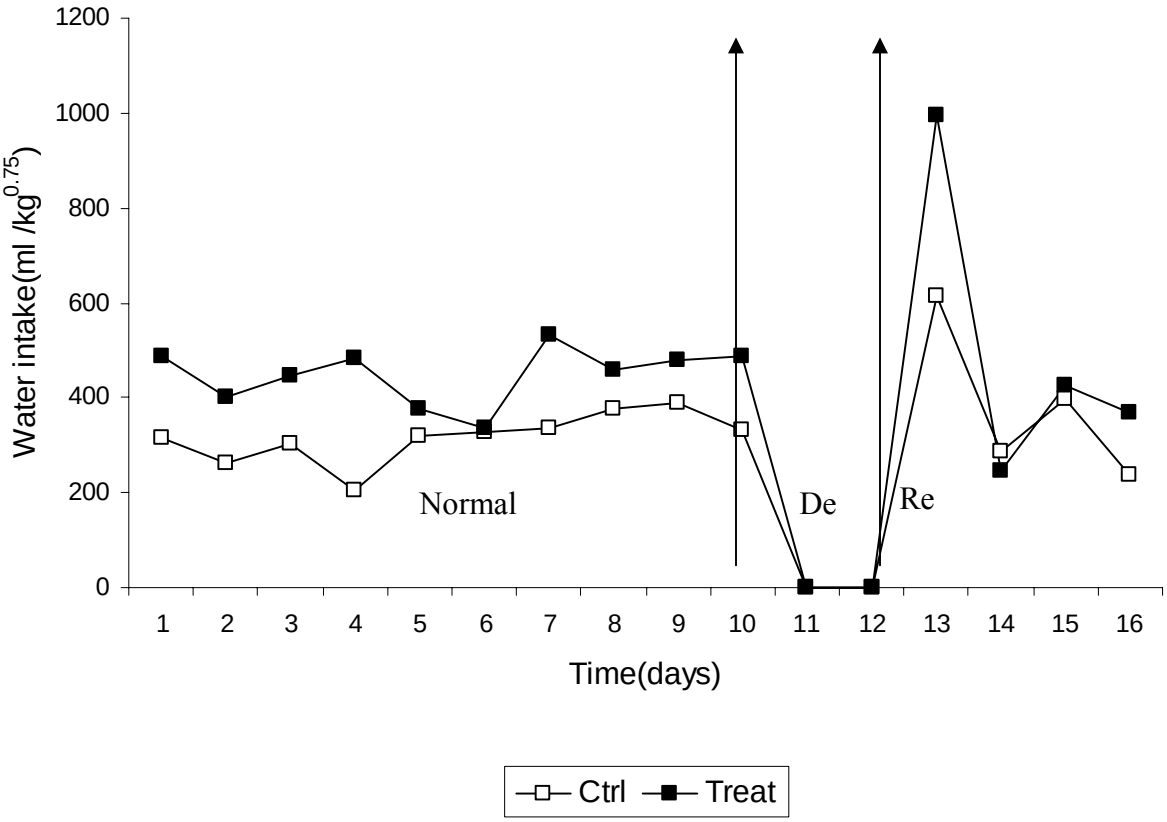


Fig. 27 Effects of saline water drinking, dehydration and rehydration on water intake of Nubian goats during wet summer.

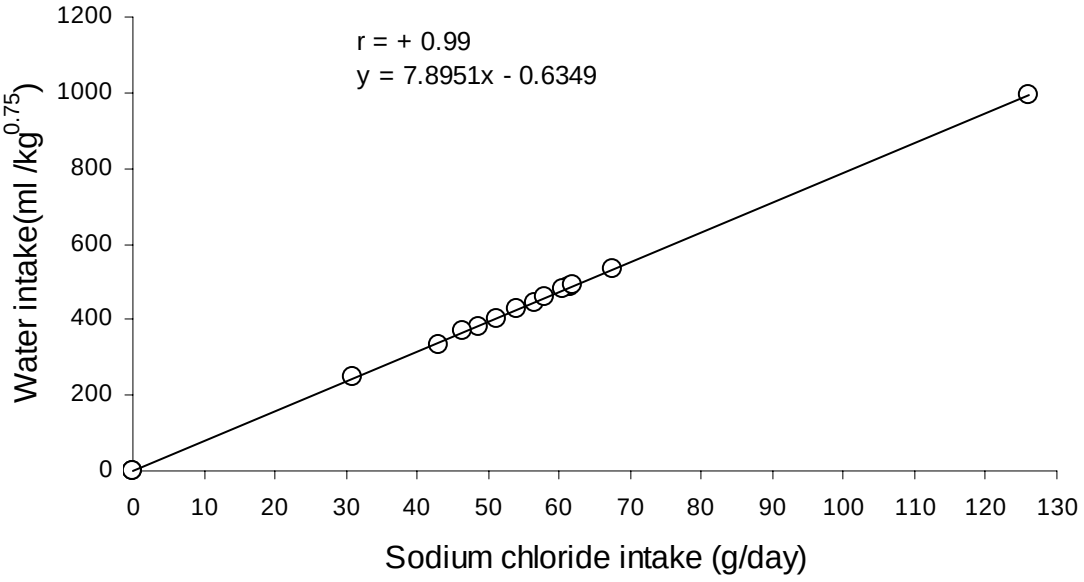


Fig. 28 Correlation between water intake and sodium chloride intake (g/day).

4.3.5 Food intake

Table 13 shows the effect of salinity of drinking water and hydration level on feed intake. The feed intake tended to be lower during the dehydration period compared to the normal hydration values. The decreases in the control and treated group in the first day of dehydration constituted 15 and 7% of normal hydrated values, respectively. On the second day of dehydration, the feed intake decreased by 61 and 41%, respectively. However, the decrease in feed intake was significant ($p<0.05$) only on the second day of dehydration for control group.

The feed intake by the control and treated groups returned to the respective normal values in days 1 and 2 of rehydration, respectively as shown in Fig. 29. There was no significant difference between the control and treated group in all experimental phases.

The ratio between the intake of water and feed intake (litres/kg) is presented in Table 12 and illustrated in Fig. 32. The highest values were obtained during the first day of rehydration period for the control and treated groups. The ratio for treated was significantly ($p<0.05$) higher compared to the control group values.

4.3.6 Body weight (BW)

The body weight gain during the experimental period of control and treated group was 0.0 and +0.5 kg, respectively. The difference did not reach

significance ($p>0.05$). During the rehydration period the BW of the control group returned to the respective initial value, while the BW of treated group was higher compared to the respective initial value.

4.3.7 Packed cell volume (PCV) and haemoglobin concentration (Hb)

Table 14 shows the effect of salinity of drinking water and hydration level on packed cell volume (PCV) and haemoglobin concentration (Hb).

The results of control group compared to respective treated group indicate that the changes in PCV and the Hb concentration for all treatments were not significant except that the PCV level during the second day of the dehydration period was significantly ($p<0.05$) higher in control group than treated group.

The PCV level of control group increased during the dehydration period above the normal value, but this difference was significant on the second day of dehydration. However, the PCV level of treated group was not significantly affected by dehydration, although it maintained apparently higher values during dehydration period. On rehydration, the PCV level of both groups returned to the normal hydration level on the second day (Fig.31a).

Table 13: The effects of drinking saline water, dehydration and rehydration on feed intake of Nubian goats during wet summer.

(n = 3, mean ± SE.M.)

Parameter	Water type	Normal	Dehydration(days)		Rehydration (days)				S.E.
			1	2	1	2	3	4	
Food intake (g/day)	Tap (Ctrl)	1064^{ab1}	900^{ab1}	418^{c1}	810^{abc1}	725^{bc1}	1220^{a1}	870^{abc1}	69.4
	Saline(Treat)	1062^{ab1}	988^{ab1}	629^{b1}	663^{b1}	1080^{ab1}	1395^{a1}	1006^{ab1}	73.0
S.E.		60.8	107	77.6	39.4	159	108	100	
Food intake ($g/kg^{0.75}$)	Tap(Ctrl)	109^{ab1}	92.3^{ab1}	42.6^{c1}	83.1^{abc1}	75.1^{bc1}	124^{a1}	89.5^{ab1}	7.02
	Saline(Treat)	100.7^{ab1}	93.1^{ab1}	59.7^{b1}	63.5^{b1}	102.8^{ab1}	131.4^{a1}	95.9^{ab1}	7.05
S.E.		7.25	10.1	7.16	8.7	16.1	7.97	9.86	
Ratio: intake of water to feed (Litres/kg DM)	Tap (Ctrl)	3.03^{b1}	-	-	7.33^{a2}	4.86^{ab1}	3.17^{b1}	2.67^{b1}	0.61
	Saline(Treat)	4.80^{b1}	-	-	17.17^{a1}	2.32^{b1}	3.26^{b1}	4.16^{b1}	1.56^{**}
S.E.		0.76	-	-	2.56	1.13	0.15	0.46	

^{a,b,c,d} Mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

^{1,2} Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error.

** $p<0.001$.

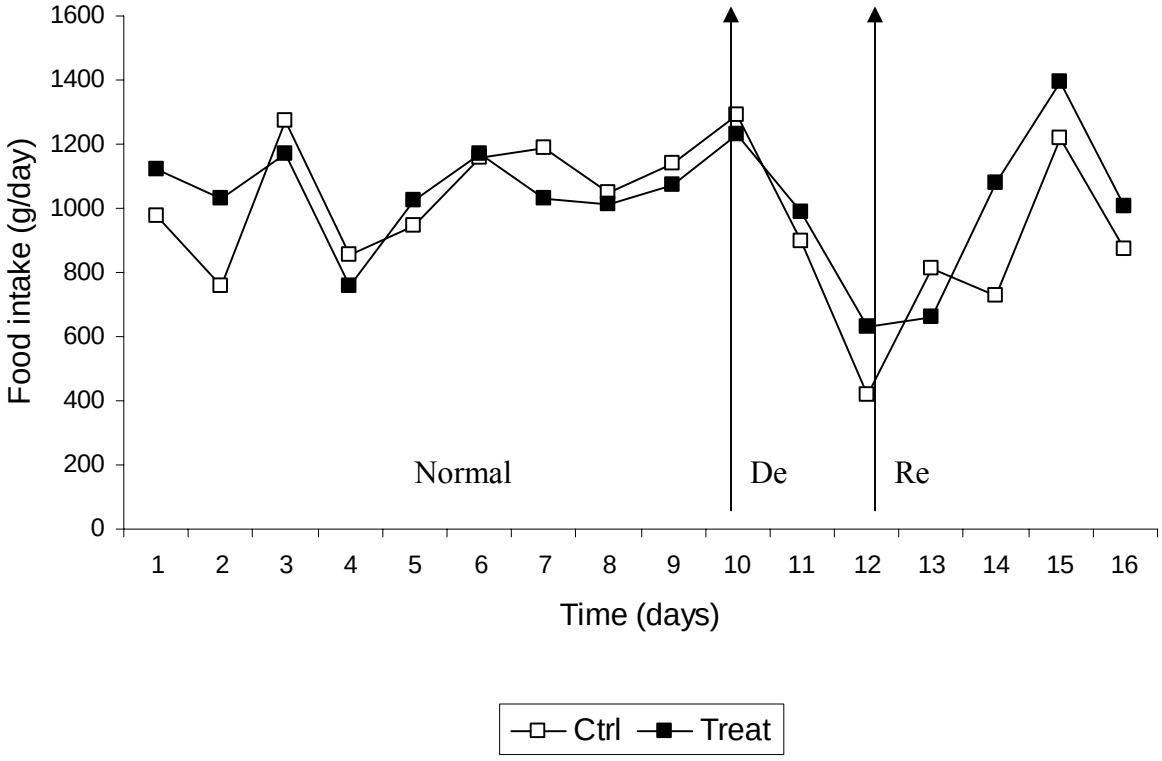


Fig. 29 Effects of saline water drinking, dehydration and rehydration on food intake of Nubian goats during wet summer.

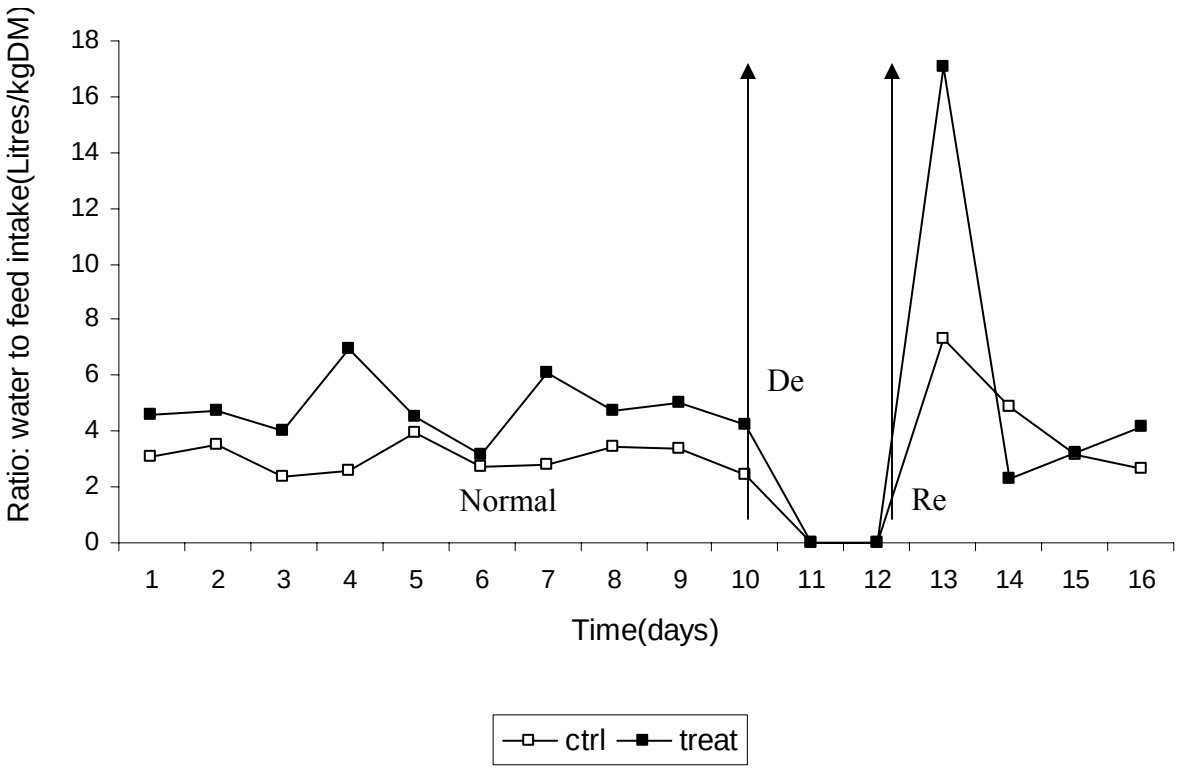


Fig. 30 The ratio between water intake and feed intake (Litres/Kg DM).

On dehydration, the Hb level of both groups increased significantly ($p<0.05$) above the normal period values, but there was no significance difference between the values obtained in the first and the second day of dehydration. In the treated group, the Hb concentration returned to the normal level on the second day of rehydration (Fig. 31 b).

4.3.8 Plasma glucose

Dehydration had no significant effect on plasma glucose level of both groups, although the values were lower during the second day of dehydration compared with the normal hydration values. The glucose level of both groups recovered after two days during the subsequent rehydration period as shown in Fig. 31 c.

4.3.9 Serum total protein (Tp), albumin (Alb) and urea

Table 14 shows the effect of salinity of drinking water and hydration level of goats on serum total protein (Tp), albumin (Alb) and urea.

The serum Tp and Alb levels tended to be higher during the dehydration period than the normal hydration period (Fig. 32 a,b), but the difference reached significance level ($p<0.01$) only for the treated group. On rehydration, the highest values of Tp and Alb were recorded during the fourth day of rehydration. On the other hand, there was no different between the control and treated groups in all of the experiment phases.

Table 14. The effect of drinking saline water, dehydration and rehydration on haemoglobin concentration (Hb),packed cell volume (PCV%) and plasma glucose level of Nubian goats during wet summer.

(n = 3, mean ± SE.M.)

Parameter	Water type	Normal	Dehydration (days)		Rehydration (days)		S.E.
			1	2	2	4	
Hb (g/dl)	Tap (Ctrl)	9.53^{b1}	12.68^{a1}	11.34^{ab1}	10.47^{ab1}	12.68^{a1}	0.47
	Saline(Treat)	8.95^{c1}	11.10^{ab1}	10.63^{ab1}	9.92^{bc1}	11.42^{a1}	0.29*
	S.E.	0.42	0.46	0.29	0.48	0.74	
PCV (%)	Tap(Ctrl)	22.56^{b1}	26.67^{ab1}	29.33^{a1}	23.0^{b1}	23.33^{b1}	0.93
	Saline(Treat)	18.89^{a1}	22.00^{a1}	23.00^{a2}	18.33^{a1}	21.00^{a1}	0.77
	S.E.	1.15	1.54	1.74	1.45	1.22	
Glucose (mg/dl)	Tap (Ctrl)	50.76^{ab1}	51.52^{ab1}	46.97^{b1}	50.0^{ab1}	57.58^{a1}	1.32
	Saline(Treat)	48.74^{a1}	46.97^{a1}	40.91^{a2}	46.12^{a1}	46.97^{a1}	1.25
	S.E.	1.01	1.91	1.52	1.8	3.57	

^{a,b,c,d} Mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

^{1,2} Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error.

* $p<0.01$.

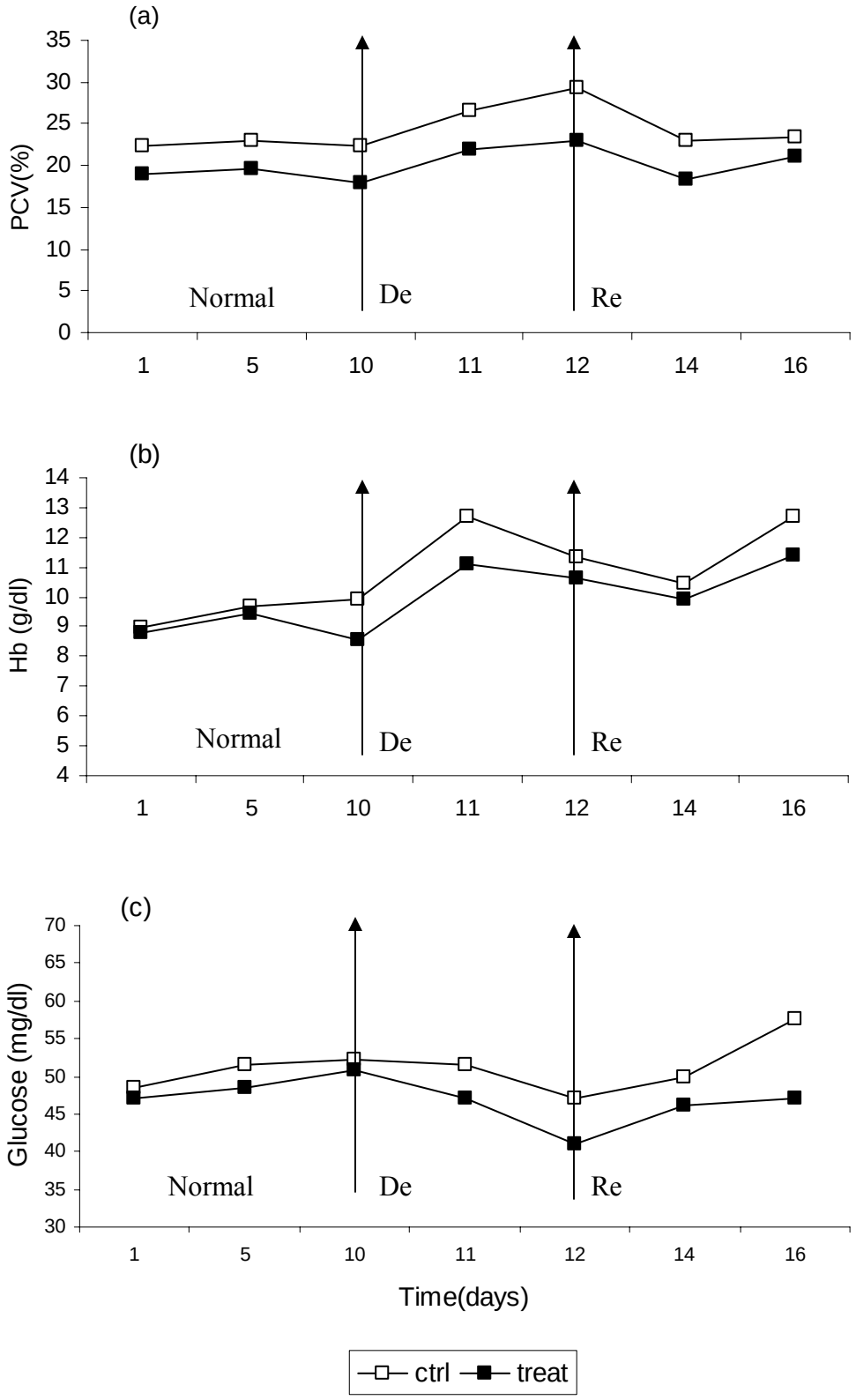


Fig. 31 Effects of saline water drinking, dehydration and rehydration on packed cell volume (PCV), haemoglobin concentration (Hb) and glucose level of Nubian goats during wet summer.

Saline water intake (1.2% NaCl) increased serum urea level significantly ($p<0.01$) above the control group in all periods. The urea level tended to be higher during the dehydration period than the normal hydration period, but this difference reached the level of significance ($p<0.01$) only on the second day of dehydration for the treated group. On rehydration, the serum urea levels of both control and treated group were significantly ($p<0.01$) higher than normal hydration level (Fig. 32 c).

4.3.10 Serum sodium (Na), potassium (K) and magnesium (Mg)

Table 16 shows the effect of salinity of drinking water and hydration level on serum electrolytes.

The serum concentrations of Na and K did not change during dehydration and rehydration periods compared with normal hydration period (Fig. 33 a,b). The Mg concentration of the treated group was significantly ($p<0.01$) higher during rehydration compared to normal hydration values (Fig. 33 c).

The Na concentration of treated group was significantly ($p<0.01$) higher than the control group during the normal hydration period. The K concentration of treated group was significantly ($p<0.05$) lower than the control group during the normal hydration and the rehydration periods. The Mg level of treated group was higher than the control group value during the second day of the dehydration and the rehydration period.

Table 15: The effects of drinking saline water, dehydration and rehydration on serum total protein, albumin and urea concentrations of Nubian goats during wet summer.

(n = 3, mean ± SE.M.)

Parameter	Water type	Normal	Dehydration(days)		Rehydration(days)		S.E.
			1	2	2	4	
Total protein (g/dl)	Tap (Ctrl)	7.84^{b1}	7.87^{ab1}	8.0^{ab1}	7.90^{ab1}	8.07^{a1}	0.03
	Saline(Treat)	7.70^{d1}	7.90^{dc1}	8.00^{bc1}	8.17^{ab1}	8.27^{a1}	0.06*
	S.E.	0.04	0.04	0.04	0.08	0.07	
Albumin (g/ dl)	Tap(Ctrl)	3.84^{b1}	3.93^{b1}	4.0^{ab1}	3.90^{b1}	4.13^{a1}	0.03
	Saline(Treat)	3.70^{c1}	3.97^{b1}	4.00^{b1}	4.17^{ab1}	4.30^{a1}	0.06*
	S.E.	0.04	0.02	0.04	0.08	0.07	
Urea (mg/dl)	Tap (Ctrl)	21.42^{c2}	22.0^{c2}	23.0^{bc2}	24.0^{ab2}	25.0^{a2}	0.41*
	Saline(Treat)	25.7^{c1}	27.0^{bc1}	27.7^{b1}	28.3^{ab1}	29.3^{a1}	0.38*
	S.E.	1.01*	1.18*	1.12*	1.01*	1.01*	

^{a,b,c,d} Mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

^{1,2} Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error.

*$p<0.01$.

Table 16: The effect of drinking saline water, dehydration and rehydration on serum electrolyte concentration of Nubian goats during wet summer.

(n = 3, mean ± SE.M.)

Parameter	Water type	Normal	Dehydration(days)		Rehydration(days)		S.E.
			1	2	2	4	
Na (mEq/L)	Tap (Ctrl)	147.9^{a2}	153.3^{a1}	153.0^{a1}	147.3^{a1}	151.5^{a1}	1.55
	Saline(Treat)	160.1^{a1}	162.7^{a1}	157.7^{a1}	158.0^{a1}	160.0^{a1}	1.14
	S.E.	3.27	2.59	3.14	2.99	2.70	
K (mEq/L)	Tap(Ctrl)	5.10^{a1}	5.00^{a1}	5.10^{a1}	5.10^{a1}	4.87^{a1}	0.04
	Saline(Treat)	4.63^{a2}	4.73^{a1}	4.80^{a1}	4.67^{a2}	4.83^{a2}	0.04
	S.E.	0.12	0.08	0.08	0.12	0.04	
Mg (mg/dl)	Tap (Ctrl)	1.30^{a1}	1.20^{a1}	1.20^{a2}	1.30^{a2}	1.20^{a2}	0.02
	Saline(Treat)	1.40^{c1}	1.37^{c1}	1.47^{bc1}	1.57^{ab1}	1.63^{a1}	0.03*
	S.E.	0.03	0.05	0.07	0.07	0.10*	

^{a,b,c,d} Mean values within the same row bearing different superscripts (letters) are significantly different at $p<0.05$.

^{1,2} Mean values within the same column bearing different superscripts (numbers) are significantly different at $p<0.05$.

S.E. Standard error.

* $p<0.01$.

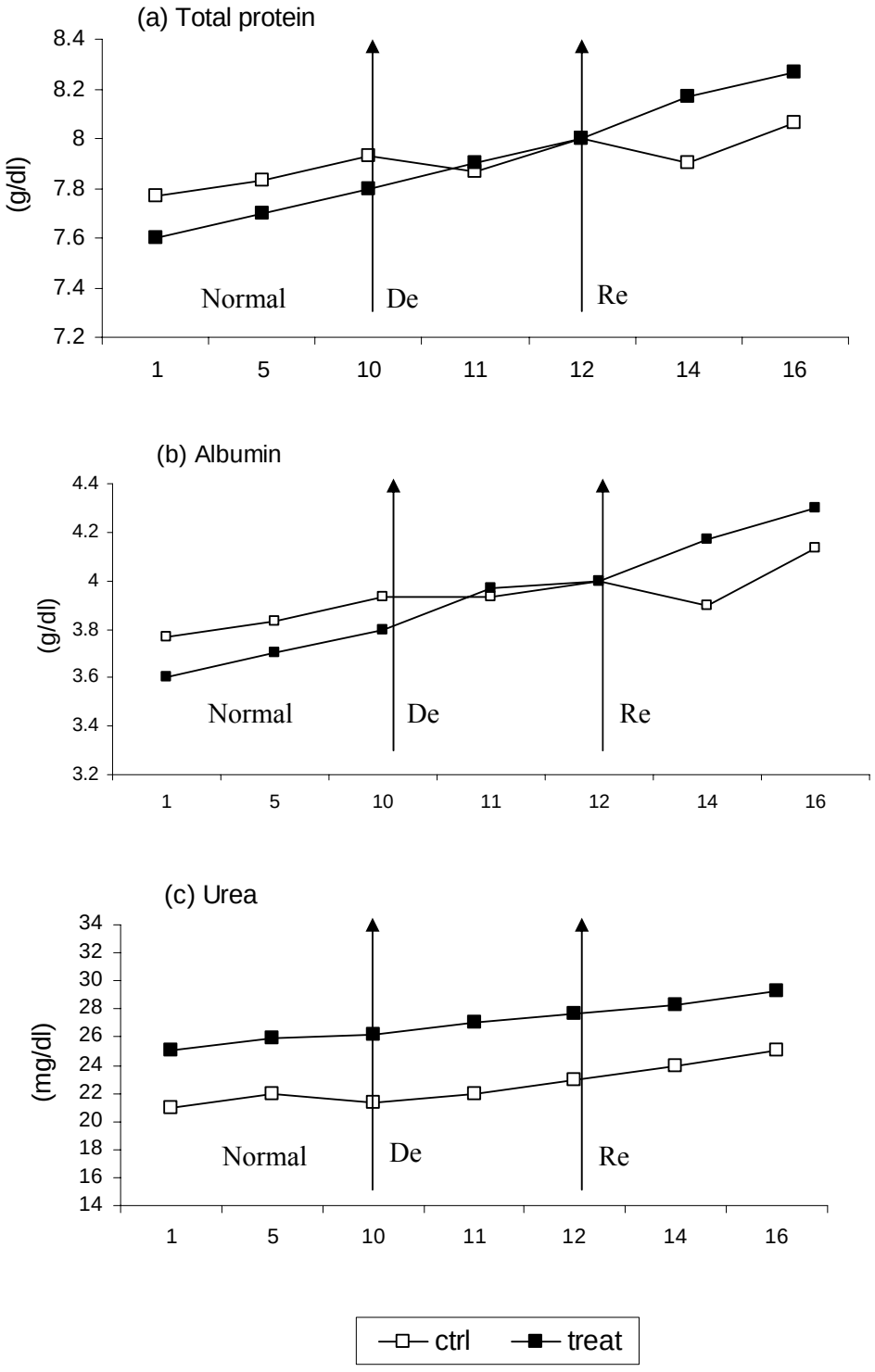
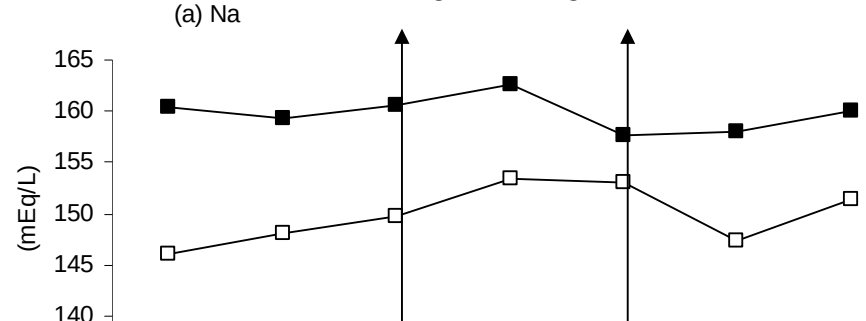


Fig. 32 Effects of saline water drinking, dehydration and rehydration on serum total protein, albumin and urea of Nubian goats during wet summer.



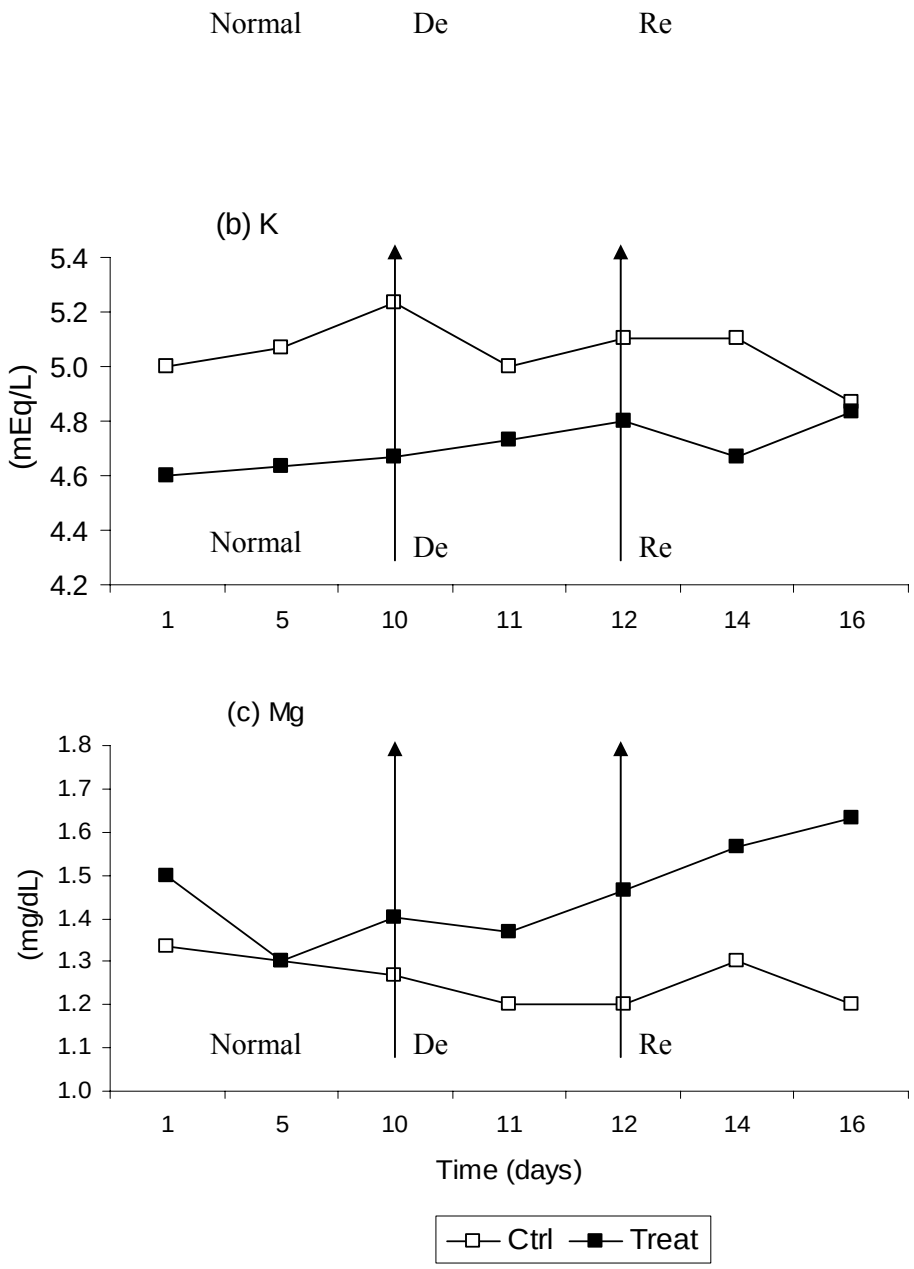


Fig. 33 Effects of saline water drinking, dehydration and rehydration on serum sodium (Na), potassium (K) and magnesium (Mg) of Nubian goats during wet summer.

4.4 Discussion

This experiment was designed to investigate the effects of saline water drinking and the state of body hydration on the physiological responses of Nubian goats.

The higher rectal temperature (Tr) of the goats during dehydration period (Table 11) is attributed mainly to decrease in the rate of evaporation which resulted from body water deficit. Yousef (1984) indicated that under restricted water condition, animals attempt to conserve water by producing concentrated urine and faeces and reducing evaporative water loss by increasing their heat storage. Olsson and Dahlborn (1989) reported that water deprivation in lactating goats during heat load (maximal daily temperature, 38 ℃; night temperature 27 ℃) reduced water loss in urine, milk and by evaporation, and increased rectal temperature. Dunson (1974) reported that one of the main mechanisms of domestic goats for reduction of water loss during dehydration appeared to be a decrease in evaporative loss. Schimidt Nielsen (1972) indicated that the body temperature of desert animals is influenced by the state of hydration. Bianca (1966) suggested that decreased evaporative heat loss could be the direct effect of dehydration and an indirect effect of a fall in feed intake and heat production.

The increase of Tr during dehydration in the present study is comparable and in agreement with the findings obtained in studies by Adogla-Bessa and Aganga (2000) in Tswana goats, Shapiro *et al*. (1986) in dogs and Nielsen (1974) in rabbits.

The increase in Tr obtained during dehydration was significant only in goats offered saline water (1.2% NaCl). This could be attributed to the needs of animals for more water to allow greater water turnover so that the body can regulate the salt balance and use more water to excrete salt in urine. The stability of Tr of goats offered tap water (control group)

during dehydration period may be related to the decline in food intake discussed before.

There was a significant increase in Tr during the day irrespective of the type of drinking water (Fig. 25). This diurnal increase in Tr is clearly associated with increase in ambient temperature during the day and increase in heat production. Abdelatif and Ahmed (1994) attributed the reduction in morning values of Tr of desert sheep to the drop in ambient temperature and enhanced dissipation of heat by sensible channels. Also the increase in Tr could be partially attributed to increase in metabolic heat production associated with enhanced muscular activity and metabolism of food. Baker *et al*. (1993) reported that the metabolic rate increased progressively with increasing the intensity of exercise for goats.

The significant decrease in respiration rate (RR) (Table 11) for both control and treated groups during water deprivation could be associated with decline of food intake (Table 13) and consequent decline in metabolic heat production. Experimental evidence has shown a decrease in food intake and metabolic heat production during water deprivation in animals (Biance *et al*., 1965; Shkolink *et al*., 1972). This depression in metabolism may help animals to maintain body water through reduction of pulmonary ventilation. Also lowering of the metabolic activity is associated with reduction in oxygen requirements and hence the rates of ventilation and respiratory frequency are reduced. The marked diurnal change in RR is clearly related to the observed rise in Tr and the need to dissipate surplus heat (Abdelatif and Ahmed, 1994).

The results indicate that in both groups water deprivation resulted in a decrease in food intake during the first and the second day of dehydration (Table 13). However, this decrease was significant only during the second day of dehydration for control group (tap water).

Fluharty *et al. (*1996) noted that a water medium is needed for both the physical softening and the biochemical digestion of feed. An adequate supply of water could therefore aid the breakdown of food and hence facilitate the fermentation and digestion processes. Furthermore, the numbers of rumen bacteria and protozoa tend to decrease following water deprivation. Also, as rumen hypertonicity has been proposed to be a major control of meal size in ruminants (Brouwer, 1965), it is possible that the intake of a substantial amount of water before and together with the meal allowed the animal to eat more food before a level of rumen fluid or perhaps systemic osmolality was reached that limited meal size. Results from studies in which rumen fluid osmolality was measured in relation to spontaneous meals in cows with unlimited access to water and during water restriction (Steiger, 2000) are consistent with the idea that an abnormal prandial increase in rumen fluid osmolality contributes to the meal size reduction during water restriction. Other possible factors include systemic hypertonicity (Steiger, 2000) and cardiovascular and vascular volume effects of feeding related to the copious production of saliva in ruminants (Baily, 1961; Carter et al., 1990; Silanikove and Tadmor, 1989).

The decline in food intake during dehydration reported in the present study is in agreement with the findings of Engell (1988) in humans, Aganga (1992, 2000) in goats, Martine *et al.* (2001) in cows, Ben Goumi (1993) in camels.

The significantly higher water intake for the group offered saline water compared with the control group during normal and rehydration period (Table 12) is attributed to the effect of NaCl on water intake discussed previously in Chapter 3.

Water intake increased significantly on the first day of rehydration compared with the normal hydration value. This observation is related to compensation of body water loss that occurred during dehydration period. Schmidt Nielsen (1964) reported that dehydrated sheep, cattle and camels can take large amounts of water rapidly when rehydrated.

The ratio of water intake to DMI (L/Kg) for both the control and treated groups was increased significantly in the first day of rehydration because of the significant increase in water intake. Also, the ratio of water intake was significantly ($p<0.05$) higher for the group of goats receiving 1.2% NaCl than control group. This is related to the higher water intake by the treated group on one hand and the lower feed intake for this group on the other hand.

Previous studies showed that the body weight decreased with water deprivation in goats (Adola-Bessa and Aganga, 2000) and sheep (Abdelatif, 1978). In the present study, the body weight was measured in the first and last day of the experiment. Thus, the results indicate no marked change related to dehydration on body weight. This may be attributed to the compensatory body weight gain during rehydration period by consumption of large amounts of water. Martine *et al.* (2001) reported that cows completely regained their body weight during the first day of rehydration, suggesting that they had mainly lost water during the water restriction period. Silanikove and Tadmor (1989) showed that body water loss accounted for 89% of the total weight loss of nonlactating beef cows during 3 days of water deprivation. Brosh *et al*. (1986) found that Black Bedouin goats did not lose body mass during dehydration except for body water.

Dehydration increased the PCV and Hb level in both groups (Fig.31 a,b), but the change in PCV level was less pronounced in the treated

group. The increase in PCV and Hb levels is related mainly to haemoconcentration which resulted from water restriction. An increase in PCV and Hb concentration during water deprivation was reported previously for goats (Muosa, 1978; Ghosh, 1983; Adogla-Bessa and Aganga, 2000) and sheep (Purohit *et al*., 1972; Turner, 1979).

The tendency of plasma glucose level to decrease during dehydration (Fig. 31 c) could be related to the depressive effect of reduction in food intake. Assad and El sherif (2002) attributed the decline in plasma glucose level in sheep to reduction in food intake. Adogla-Bessa and Aganga (2000) suggested that water deprivation raised the concentrations of blood biochemical constituents due to dehydration. A decrease in plasma glucose level in response to water restriction has been reported previously by Abdelatif and Ahmed (1994) in sheep, Martine *et al*. (2001) in cows and Ben Goumi (1993) in camels.

The serum concentration of total protein (Tp) and albumin (Alb) were higher during dehydration period than normal hydration period for both groups (Table 15); but the increase reached significance level only for the treated group. The increase in Tp and Alb levels is related mainly to haemoconcentration as discussed before. Khan (1978) reported that when water was deprived from the Barmer goats for 4 days, the total plasma proteins, plasma globulins and albumin concentrations were increased.

The increase in Tb and albumin during dehydration was significant only for the treated group. This result may be attributed to the higher haemoconcentration for the treated group compared to the control group during dehydration.

In the present study, the serum urea level tended to be higher during the dehydration period (Table 15), but this increase reached significance

level only for the treated group. This increase in urea level may be related partially to antidiuretic hormone (ADH). Olsson and Dahlborn (1989) reported that water deprivation increased ADH for goats and this would have opposed urea loss, as ADH promotes urea reabsorption (Meintjes *et al.*, 2004). Also it could be associated with an increase in catabolism of body protein (Houpt, 2004). The amount of urea present in blood may increase due to decrease in urine volume following water restriction, and the amount of urea reabsorbed in the kidney varies with changes in urine volume (Cantarow and Schepartz, 1957). An increase in blood urea level during water restriction has been reported previously in goats (Aganga *et al.*, 1988), sheep (Abdelatif and Ahmed, 1994) and cattle (Martine *et al*., 2001).

The serum concentration of macrominerals Na, K and Mg were not affected significantly by water deprivation (Table 16). Adogla-Bessa and Aganga (2000) reported that water deprivation raised the concentrations of blood biochemical constituents due to dehydration in goats. Blair-West *et al*. (1972) and Zucker *et al*. (1982) reported reduced blood aldosterone levels in dehydrated sheep and dogs, suggesting that reduced mineralocorticoid action may be involved in Na loss during dehydration. Thus, the stability of plasma Na and K levels during dehydration could be related to the fact that the depressive effect of aldosterone has been counterbalanced by the effect of haemoconcentration. Khan (1978) reported that the plasma Na and K remained unchanged throughout the water deprivation regime in Barmer goats.

In the present study, the plasma Mg level for the control group was not influenced by haemoconcentration that may have occurred during dehydration period; this may be related to observed reduction in food intake and subsequent lowering in mineral intake. Underwood *et al*.

(1999) reported that the circulating levels of magnesium are influenced by the supply of absorbed magnesium from the gut. Thus, fasting causes a rapid fall in serum magnesium (Littledike and Goff, 1987). The results show that drinking saline water (1.2% NaCl) increased Mg level compared with tap water. Studies with the isolated rumen showed that sodium decreased the potential difference and enhanced absorbability of Mg from the rumen (Martens and Blume, 1986).

The results indicate that after two days of rehydration, most of parameters which were affected by dehydration returned to the steady state values recorded at the normal hydration period. But there was a marked increase in Hb, Tp, Alb, serum urea and Mg levels on the 4^{th} of rehydration. These results may be attributed to the higher food intake observed during the 3^{rd} and 4^{th} day of rehydration.

4.5 Summary

(1) The effects of saline water drinking (1.2% NaCl) and the state of body hydration on thermoregulation, water and food intake and blood composition have been investigated in Nubian goats during wet summer.

(2) The rectal temperature (Tr) increased significantly in the group receiving saline water during dehydration period.

(3) The respiration rate (RR) decreased significantly for both control and treated groups during water deprivation.

(4) The values of Tr and RR obtained at 2:30 p.m were significantly higher than the values recorded at 8:30 a.m.

(5) Water intake (ml/day) of the treated groups was significantly higher compared to respective control group values. In both control and treated groups, water intake by the goats on the first day of rehydration was significantly higher compared to the normal hydration value.

(6) In both groups, water deprivation decreased food intake by the goats.

(7) Water deprivation increased the packed cell volume (PCV) and haemoglobin concentration (Hb) of both groups. On rehydration, the PCV and Hb concentration returned to the normal hydration level on the second day.

(8) The serum total protein (Tp), albumin (Alb) and urea level increased significantly during water deprivation for the treated group. The serum urea level increased significantly for treated group compared to respective control group values.

(9) The serum concentration of Na was significantly higher in the treated group compared to the respective control group value during the normal hydration period.

(10) The serum concentration of K was significantly lower in the treated group compared to the respective control group value during the normal hydration and rehydration periods.

(11) The serum Mg level was significantly higher in the treated group compared to the respective control group value during the second day of dehydration and the rehydration periods.

CHAPTER FIVE

GENERAL DISCUSSION AND CONCLUSIONS

The biological efficiency of goats in meat, fibre and milk production renders them especially suitable for small-scale production in harsh environments. In such ecosystems, the animals often have to drink water from different sources and to experience short or long periods of water and feed shortage, generally under intense solar radiation. These environmental factors constitute a permanent challenge to productivity and to the homeostatic mechanisms regulating energy and fluid balance.

In this thesis the effects of quality and quantity of drinking water on the physiological responses of Nubian goats as influenced by the seasonal changes in the thermal environment have been investigated. The effects of increasing the salinity of drinking on the responses of Nubian goats were assessed during summer and winter (Chapter 3). Also the effects of interaction between saline water drinking and the state of body hydration have been investigated under wet summer condition (Chapter 4).

The thermoregulatory responses of the goats indicate that the increase in NaCl concentration in drinking water had no significant effect on Tr of the goats, but when the animals were subjected to 48h dehydration, Tr increased significantly only in goats offered saline water. This result indicated that there was a combined effect of salt load and dehydration on thermoregulation in goats. The effect of dehydration on Tr could be attributed to reduction in evaporative heat loss by animals, and the additive effect of saline water could be attributed to the needs of animals for more water to allow for greater water turnover so that the body can regulate the salt balance and use more water to excrete salt in

urine. Dahlborn (1989) reported that water deprivation in lactating goats during heat load (maximal daily temperature, 38 °C, night temperature 27 °C) reduced water loss in urine, milk and by evaporation, and increased rectal temperature. On the other hand, Adogla-Bessa and Aganga (2000) found that 48 h water deprivation had no effect on both Tr and RR in Tswana goats. In this study the food offered to Tswana goats about 9% water, while in the present study the goats were offered dry food; moreover the length of the study of Tswana goats was longer (365 days) than in the present study, this may have resulted in an adaptation of Tswana goats during dehydration periods. Thus, the response of Nubian goats to varying level of water deprivation during long periods should be examined.

The results also indicate that when water was offered during the rehydration period, Tr of the goat decreased progressively (Fig. 25) as a result of increasing evaporative heat loss. Upon rehydration, the goats start to sweat within minutes; this happens before the water intake has caused any change in plasma osmolality (Baker, 1989). The act of drinking caused a rapid transient rise in arterial blood pressure, an increase in plasma adrenaline and noradrenaline concentrations and an immediate fall in the elevated plasma vasopressin concentration in goats (Olsson and Baker, 1989). It has been proposed that these reactions were associated with nervous reflexes initiated by receptors in the mouth that were stimulated by the drinking of fluid (Thrasher *et al*., 1981) and that the reflexes are involved also in the onset of sweating (Baker, 1989). Olsson and Dahlborn (1989) reported that evaporative heat loss was higher in lactating goats when rehydrated.

The present results indicate that the Tr and RR were significantly affected by seasonal changes. The higher values of Tr of goats measured

during summer is clearly attributed to the increase in heat gain from the thermal environment as there was a direct positive correlation between Tr and ambient temperature (Fig. 5). The increase in RR is a normal physiological response to dissipate heat from the body and to reduce hyperthermia as indicated by El Hadi *et al*. (1977) and Abdelatif (1978). Yeates (1965) pointed out that cooling by respiratory evaporation is relatively inefficient when compared to sweating because of the increased physical exertion of faster breathing and the resultant heat generation. Baker (1982) and Robertshaw and Dmi'el (1983) reported that panting serves two purposes; first, panting involves no losses of salt and thereby blood plasma volume is better preserved. Second, panting involves cooling of the blood passing the nasal area, which makes it possible to keep brain temperature lower than deep body temperature, this is important since the dehydrated goat can not prevent its deep body temperature to rise in a hot environment.

In the present study, the significant increase in RR during the first day of dehydration for both control and treated group indicates that the goats used panting to reduce body temperature and to conserve water loss by sweating. Dmi'el, (1986) reported that when the Bedouin goats become dehydrated, sweating from the trunk subsides, but it still sweats on the head, which makes it possible to keep the head region cooler. Baker (1989) reported that as dehydration continues, sweating is suppressed and the animals rely more and more on panting. Olsson and Dahlborn (1989) reported that 29.5 h water deprivation increased the RR of lactating and non-lactating goats.

The significant decrease in respiration rate RR (Table 11) for both control and treated groups during the second day of water deprivation could be associated with decline in food intake (Table 13) and consequent

decline in metabolic heat production. This depression in metabolism may help animals to maintain body water through reduction of pulmonary ventilation. Also lowering of the metabolic activity is associated with reduction in oxygen requirements and hence the rates of ventilation and respiratory frequency are reduced. The marked diurnal change in RR is clearly related to the observed rise in Tr and the need to dissipate surplus heat.

In the present studies, both water and food intake by the goats were influenced significantly by NaCl concentration in drinking water, seasonal changes in thermal environment and the state of body hydration. An increase in NaCl concentration from 0.8 to 1.6% in the drinking water increased water consumption by the goats significantly (Table 4); on the other hand, 2% NaCl decreased water consumption by the goats. This indicates that goats can tolerate 1.6% NaCl, but when the concentration was increased to 2%, the goats reduced the saline load by reducing the amount of water intake. The tolerance of animals to salinty of drinking water is influenced by species, environment and adaptation. Macfarlane (1971) and Maloiy (1972) reported that goats tolerated water contaning 1.5% salt. Peirce (1957, 1965) reported that sheep tolerated water containing 1.3% NaCl, but with 2% NaCl, feed consumption and body weight declined and some animals became weak and emaciated. Goatcher and Church (1970) reported that goats have similar or slightly greater tolerances to salt in water compared with sheep. Studies on cattle showed that the animals on 2% NaCl in drinking water drank less than those on 1% NaCl (Weeth *et al*., 1960). At high environmental temperatures and dry conditions, the tolerable salt concentration is reduced, because of increase in water consumption (Settle *et al*., 1999). In the present study,

the depressive effect of high salinity of water intake on food intake was more pronounced during summer (Table 5).

The increase in water intake when salinity was increased from 0.8 to 1.6% NaCl may be related to stimulation of the hypothalamic region which is affected by Na concentration in the extracellular fluid and the plasma osmolality. William (2004) reported that the plasma osmolality is maintained within narrow limits by appropriate adjustments of water intake and excretion. These adjustments are governed by centres in the hypothalamus that influence both secretion of ADH (water excretion) and thirst (water intake). The osmoreseptors respond mostly to changes in Na concentration in the ECF because Na and its accompanying anion constitute about 90% of the effective osmotic pressure of ECF. Loading with Na tends to produce an expansion of ECF volume and osmotic pressure, and Na^+ excretion by the kidneys rises in an attempt to lower the volume toward normal (William, 2004). An increase in water intake in response to saline loading has been reported previously in goats (Thornton *et al*., 1985; Abou Hussien *et al.,* 1994; El Gawad, 1997) and sheep (Houpt, 1993; Meintjes *et al*., 2004).

In the present study, the significant decrease in food intake by the goats receiving high concentrations of NaCl (1.6 and 2%) in the drinking water (Table 5) may be attributed to the decrease in water intake by the goats receiving high concentrations of saline water. Water intake is related to dry matter intake. During eating, especially in hungry animals that eat rapidly, the saliva and other gastric juices start to flow. This leads to hypovolaemia and hyperosmolality (Blair-West and Brooks, 1969), which explains why ruminants drink mostly in connection with feeding. Also the decrease in food intake may be attributed to the effect of salinity on rumen flora and saliva secretion. Food intake during a meal can be

limited by the rise in osmolality of ruminal fluid, which is sensed in the wall of the rumino-reticulum. Phillips *et al*. (1981) observed a linear decrease in food intake associated with an increase in the osmolality of ruminal fluid as a result of ruminal infusions of NaCl solutions. Richard *et al*. (1990) reported that the tonicity of plasma increases toward the end of a large meal as a consequence primarily of absorption of VFA and Na from the rumen and fluid shifts into the gut. This hypertonicity inhibits parotid secretion by a reduction in the parasympathetic stimulation to the gland. Decreases in the flow rate of both parotid and total saliva have been reported in goats following infusions of hypertonic NaCl solution into the CSF of the lateral cerebral ventricle (Olsson, 1976) and also in sheep following intravenous infusions of hypertonic solutions (Warner and Stacy, 1977).

An adverse effect on the rumen flora could have retarded digestion of the food, with decreased rate of its passage through the alimentary tract, and consequently it reduced food consumption. Wilson (1965) reported that the intake of salt bush by sheep decreased to less than half when the drinking water was replaced by water containing 0.9 or 1.2% NaCl. He concluded that in sheep dependent entirely on salt bush, the drinking water should contain not more than 0.6% NaCl.

From the results of the present study it could be concluded that in both winter and summer thermal environments, the drinking water for goats should contain not more than 1.6% NaCl.

In the present studies, water deprivation resulted in a decrease in food intake during the first and the second day of dehydration regardless of the quality of water (Table 13). However, the decrease in food intake was significant only on the group offered tap water. This indicated that adding 1.2% NaCl to the drinking water leads to alleviation of the

depressive effect of dehydration on food intake. Fluharty *et al. (*1996) noted that a water medium is needed for both the physical softening and the biochemical digestion of feed. An adequate supply of water could therefore aid the breakdown of food and hence facilitate the fermentation and digestion processes. Furthermore, the numbers of rumen bacteria and protozoa tend to decrease following water deprivation.

On rehydration, the water intake by goats increased significantly on the first day compared with the normal hydration value. This observation is related to compensation of body water loss that occurred during dehydration period. Schmidt Nielsen (1964) reported that dehydrated sheep, cattle and camels can take large amounts of water rapidly when rehydrated. However, in the present study, the water intake on the first day of rehydration was significantly higher in the group receiving saline water compared to the control group level; this could be related to the fact that the goats used more water to excrete NaCl in the urine. The results suggest that when goats receiving saline and subjected to dehydration and rehydrated, they need more water to compensate the body water deficit and regulate NaCl in the body.

The results showed that the intake of both tap water and saline water by the goats was influenced by seasonal changes in thermal environment. The water consumption of goats was significantly higher during summer compared to values measured during winter (Fig. 7). This is attributed to using more water for heat dissipation from the body and to reduce hyperthermia by evaporative cooling. The change in water intake in response to seasonal change in thermal environment is in agreement with the findings reported by Adogla-Bessa and Aganga (2000); the authors reported that the mean consumption of water by Tswana goats was higher

during summer (1889 ml/day) compared to the value measured in winter (950 ml/day).

The current studies indicate that 1.6% NaCl in drinking water resulted in a significant decrease in the mean body weight of the goats only during winter compared to the respective control group (Table 5). This result could be related partially to the reported reduction in food intake with 1.6% NaCl in drinking water during winter. Peirce (1957) reported that the changes in body weight of animals are presumably the direct consequence of changes in food consumption. The influence of salt load in the drinking water on body weight has been investigated previously in sheep (Peirce, 1957, 1963; Wilson, 1966) and cattle (Weeth *et al.*, 1960). The authors reported that a concentration of 1.0 % NaCl in the drinking water had no adverse effects on the body weight of animals, but there was a decline in body weight of several animals receiving 2.0 % NaCl in drinking water.

The results showed that the body weight of goats was influenced by seasonal change in thermal environment. The decrease in body weight of the goats offered 1.2% NaCl in drinking water compared to respective control group values was significant only during winter (Table 5). This result could be attributed to the use of nutrients for heat production in the rather cool winter environment. Stefan *et al*. (1977) reported that in conscious goats cooling the anterior hypothalamus increased heat production.

The current results showed that when the goats were subjected to 48 h dehydration followed by 4 days of rehydration, the body weight values for both control and treated groups were not significantly different compared to initial values. This may be attributed to the compensatory body weight during rehydration period associated with intake of large

amounts of water. Previous studies showed that a decrease in body weight with water deprivation in Tswana goats (Adogla-Bessa and Aganga, 2000) and desert sheep (Abdelatif, 1978).

The current results indicate that the PCV and Hb concentration were influenced significantly by water and food consumption related to saline load and seasonal changes in thermal environment (Table 6). There was a marked decrease in both indices for the groups receiving 1.2 and 1.6% NaCl in drinking water compared to respective control group values during summer. William and Swenson (2004) reported that the nutritional status, blood volume and environmental temperature may affect the PCV level and Hb concentration in animals. In the present study, the significant increase in PCV and Hb concentration during dehydration (Table 14) associated with haemoconcentration that resulted from deprivation of water.

In winter, the highest values of PCV and Hb concentration for the treated groups were obtained with 2% NaCl. This may be attributed to haemoconcentration associated with decrease in water intake due to the increase in NaCl concentration in the drinking water, particularly during winter.

Water deprivation influenced the plasma glucose level. In the present study the tendency of plasma glucose level to decrease during dehydration (Fig. 31c) could be related to the depressive effect of reduction in food intake. Assad and El sherif (2002) attributed the decline in plasma glucose level in sheep to reduction in food intake. A decrease in plasma glucose level in response to water restriction has been reported previously by Abdelatif and Ahmed (1994) in sheep, Martine *et al*. (2001) in cows and Ben Goumi (1993) in camels.

In the present study, the serum concentrations of total protein (Tp) and albumin (Alb) were affected by salinity of drinking water and season. During winter, Tp and Alb concentrations increased significantly by gradual increase in salinity of drinking water. This may be attributed to haemoconcentration due to the increase in NaCl concentration in the drinking water, particularly during winter.

Water deprivation increased the concentrations of serum Tp and Alb in goats (Fig. 32 a,b); but this increase reached significance level only for the group receiving saline water (Table 15). This indicates that there was a combined effect of dehydration and saline load that resulted in a higher haemoconcentration in the treated group compared to the control group during dehydration. Khan (1978) reported that when water was deprived from Barmer goats for 4 days, the total plasma protein, plasma albumin and globulins concentrations were increased. During two days of rehydration, Tb and Alb concentrations returned to the normal steady state values measured at the normal hydration period only for the group receiving tap water, while Tb and Alb concentrations of treated group (1.2% NaCl) remained high. This may be attributed to the high food intake by treated group on the second day of rehydration (Table 13).

The serum urea level was significantly affected by the salinity of drinking water (Table 7). In the current results, there was a significant decrease in serum urea level for the groups receiving high concentrations of NaCl in the drinking water compared to the other experimental groups during both seasons (Table 6). Meintjes and Engelbrecht (2004) reported that in sheep, the delivery of urea to the rumen is enhanced by the intake of saline drinking water, and that this may have an effect on plasma urea concentrations, or possibly under conditions of excessive salt intake, the

kidney adjusts the ratio of urea to sodium in the medullary interstitium in favour of the former.

Water deprivation influenced the serum urea level for both control and treated groups of goats (Table 15). The significant increase in urea concentration with 48 h water deprivation indicates that urea recycling of goats was enhanced at this level of water restriction when the food intake by the goats was lower. The return of urea via the blood and saliva to the gastrointestinal tract of ruminants provides a valuable source of nitrogen to rumen microbes for protein synthesis (Godwin and Williams 1986). Therefore, the role of the kidney in conserving urea particularly during periods of low nitrogen intake during drought conditions, is of immense importance in the ruminant (Meintjes and Engelbrecht, 2004). In this respect, it was established that restriction of water intake for 3 days results in an upgrading of urea transporter mRNA in the inner stripe of the outer medulla (Shayakul *et al*., 2000). Also the increase in plasma urea during dehydration may be related to the effect of antidiuretic hormone (ADH). Olsson and Dahlborn (1989) reported that water deprivation increased ADH for goats and this would have opposed urea loss, as ADH promotes urea reabsorption (Meintjes *et al.*, 2004).

There was a significant increase in serum Na concentration in groups receiving saline water compared to the respective values obtained for the control group (Table 8). The increase in serum Na concentration in goats consuming saline water may be associated with increase in NaCl intake through the drinking water. The higher plasma Na concentration stimulates ADH secretion and thirst which lead to increase in plasma volume. Hypernatraemic hypervolaemia increases the glomerular filtration rate, the aldosterone secretion falls and the reabsorption of Na in

the kidneys and gut decreases to a minimum eliminating the extra Na (Holtenius and Dahlborn, 1990).

The serum K level decreased significantly with increasing the salinity of drinking water in both season (Table 8). This decline is attributed to the decrease in food intake by the goats and to the increase of K excretion by renal system as a result of salinity of drinking water. Previous studies have reported an increase in urinary volume and K excretion during saline water drinking in sheep (Potter, 1963) and cattle (Weeth and Leperance, 1965). Potter (1968) found an increase in K excretion during acute Na loading in sheep adapted to either rain water or salt water drinking. Also Wesson (1969) reported that the renal excretion of K in humans and dogs increased in response to an increase in Na load.

In the present study, the serum Mg concentrations were higher in treated groups compared to respective control group values (Table 8, 16). Studies with the isolated rumen showed that Na decreased the potential difference and enhanced absorbability of Mg from the rumen (Martens and Blume, 1986).

During the dehydration period, the serum Na, K and Mg concentration were not affected significantly in the present study (Table 16). This suggests that goats could regulate the minerals level during 48 h of water deprivation. Reduced blood aldosterone levels in dehydrated sheep (Blair-West *et al*., 1972) and (Zucker *et al*., 1982) dogs, suggesting that reduced mineralocorticoid action may be involved in Na loss during dehydration. Adogla-Bessa and Aganga (2000) reported that water deprivation raised the concentrations of blood constituents due to dehydration in Tswana goats. Thus, the stability of plasma Na level during dehydration could be related to the fact that the depressive effect of aldosterone on Na level has been counterbalanced by the effect of

haemoconcentration. Khan (1978) reported that the plasma Na and K remained unchanged throughout the water deprivation in Barmer goats.

The results indicate that in both seasons the goats controlled the salt load while drinking saline water by excreting more urine in order to reduce the high salt load resulting from high consumption of saline water. Thus, in both seasons there was a significant increase in urine urea, Na, K and Mg concentrations with increasing NaCl concentration in the drinking water (Table 9). Potter (1968) indicated that in sheep, drinking saline water caused an increase in both GFR and excretion of Na and K. Also, atrial natriuretic peptide (ANP) has a potent effect on increasing the excretion of Na (Sonnenburg, 1990). Meintjes and Engelbrecht (2004) reported that during the phases of salt loading, natriuresis was obligatory for homeostasis. Also Wesson (1969) reported that the renal excretion of K in humans and dogs increased by an increase in Na load.

The results of this study indicate that with high salinity of drinking water, Nubian goats protected themselves from salt stress by lowering the amount of water intake, and the kidneys regulated the increase of blood macrominerals resulting from high consumption of saline water by increasing the excretion of these constituents in urine.

Although Nubian goats are usually kept under riverine conditions, these findings in the present study have some implications in relation to the management of different breeds of goats herded in semi-arid regions, and may also be utilized for planning the distribution of water schemes in dry areas of the tropics.

In the present study, the regulation of excesses NaCl were related to the kidneys functions. Therefore, future studies should investigate the role of kidneys in homeostasis during salt loading. The effects of salinity of drinking water on the volume, composition and osmolality of body

fluids should be assessed. Also the responses of animals to drinking water containing NaCl with other macrominerals should be examined. Since the regulation of NaCl is related to endocrine responses, the effects of salt loading on endocrine system should be assessed.

REFERENCES

Abdelatif, A.M. (1978). Comparative Study of the Effect of Heat on Water Balance in Desert Sheep and Nubian goats. M.V.Sc. Thesis University of Khartoum.

Abdelatif, A.M. and Ahmed, M.M.M. (1994). Water restriction, thermoregulation, blood constitutes and endocrine responses in Sudanese desert sheep. Journal Arid. Environments, 26: 171-180.

Abou Hussien, E.R.M., Gihad, E.A., El-Dedawy, T.M. and Abdel Gawad, M.H. (1994). Responses of camels, sheep and goats on saline water. 2. Water and mineral metabolism. Egyptian Journal of Animal Production Supplement, 31: 387-401.

Adogla-Bessa and Aganga, A.A. (2000). Responses of Tswana goats to various lengths of water deprivation. South African Journal of Animal Science, 30(1): 87-91.

Adolph, E.F. (1947). Urges to eat and drink in rats. American Journal Physiology, 151: 110-125.

Aganga, A.A. (1992). Water utilization by sheep and goats in Northern Nigeria. World Animal Review FAO, 73: 9-14.

Aganga, A.A., Alabi, O. and Momoh, M. (1988). Effect of water deprivation on nutrient digestibility, nitrogen retention, and water excretion in Yankasa sheep and Maradi goats. Nigerian Journal Animal Production, 15: 139-143.

Ahmed, M.M. and Ammar, I.E. (2001). Effects of water and feed restriction on body weight change and nitrogen balance in desert goats fed high and low quality forages. Small Ruminant Research, 41(1):19-27.

Ahmed, M.M. and El Kheir, I.M. (2004). Thermoregulation and water balance as affected by water and food restrictions in Sudanese desert goats fed good-quality and poor-quality diets. Tropical Animal Health Production, 36(2):191-204.

Alaku, O. and Moruppa, S.M. (1983). Dry season weight losses in Red Sokoto (Maradi) goats reared in the Sahel region of northeastern Nigeria. International Journal of Biometeorology, 27: 143–156.

Ali, K.E., Mousa, H.M. and Hume, I.D. (1982). The total body water and water economy in camels, desert goats and desert sheep during water restriction and deprivation. Yugoslav. Physiology Pharmacology Acta, 18: 229-236.

Andersson, B.E. (1971). Regulation of water intake. Physiology Reviews, 58(3): 582-601.

Andersson, B.E. and Jonasson, W. (1993). Temperature regulation and environmental physiology. In: Dukes, Physiology of Domestic Animals. (Edited by Swenson, M.J. and reece, W.O.), Eleventh Edition: pp. 886-895. Comstock Publishing Associates Cornell University Press. Ithaca, London.

Arab Organization for Agricultural Development (AOAD) year book of agricultural statistics. Khartoum University S/78.

ARC (1980). Nutrient Requirements of Ruminants. Commonwealth Agricultural Bureaux, Farnham Royal, UK, Pp. 213-216.

ARC. (1966). The nutrient requirements of farm livestock. No. 3 (Pigs). Agriculture Research Council, London.

Arieli, A., Naim, E., Benjamin, R.W. and Pasternak, D. (1989). The effect of feeding saltbush and sodium chloride on energy metabolism in sheep. Animal Production, 49: 451-457.

Arnold, G.W. (1964). Some principles in the investigation of selective grazing. Proceedings of the Australian Society Animal Production, 5:258-271.

Assad, F. and El-sherif, M.M.A. (2002). Effect of drinking saline water and feed shortage on adaptive responses of sheep and camels. Small Ruminant Research, 45: 279-290.

Assad, F., Bayoumi, M.T. and Khamis, H.S. (1997b). Impact of long-term administration of saline water and protein shortage on haemograms of camels and sheep. Journal Arid Environments, 37: 71-81.

Bailey, C.B. (1961). Saliva secretion and its relation to feeding in cattle. The rate of secretion of mixed saliva in the cow during eating with an estimate of magnitude of the total daily secretion of mixed saliva. British Journal of Nutrition, 15: 433-451.

Baker, M.A. (1982). Brain cooling in endotherms in heat and exercise. Annul Review of Physiology, 44: 85-96.

Baker M.A. and Nijland, M.J. (1993). Selective brain cooling in goats: effects of exercise and dehydration. The Journal of Physiology, 471:679-92.

Baker, M.A. (1989). Effects of dehydration and rehydration on thermoregulatory sweating in goats. The Journal of Physiology London, 417: 421-435.

Bartholomew, G.A. and Tucker, V.A. (1963). Control of changes in body temperature, metabolism, and circulation by the agamid lizard, Amphibolurus barbatus. Physiology Zoology, 36:199–218.

Bartholomew, R.J. and Delany, A.M. (1966). Proceedings of the Australian Association Clinical Biochemists, 1: 214.

Beede, D.K. and Myers, Z.H. (2000). Water nourishment of dairy cattle. Proceedings of the 24th Quebec Symposium on Dairy Nutrition. Saint-Hyacinthe, Quebec, Canada. October 19.

Bell, F.R. (1995). Preception of sodium and sodium appetite in farm animals. In: Phillips, C.J.C. and Chiy, P.C. (eds) Sodium in Agriculture. Chalcombe Publications, Canterbury, UK, pp. 82-90.

Ben Goumi, M., Riad, F., Giry, J., de la Farge, F., Safwate, A., Davicco, M.J. and Barlet, J.P. (1993). Hormonal control of water and sodium in plasma and urine of camels during dehydration and rehydration. General and Comparative Endocrinology, 89(3):378-386.

Berger, L.L. (1990). Comparison of National Research Council feedstuff mineral composition data with values from commercial laboratories. In: Proceedings of Georgia Nutrition Conference, Atlanta, 1990, University of Georgia, Atlanta, pp. 54-62.

Bianca, W. (1966). Heat tolerance in dehydrated steers. Journal of Agricultural Science, 66: 57-60.

Blair-West, J.R., Brook, A.H. and Simpson, P.A. (1972). Renin responses to water restriction and rehydration. The Journal of Physiology, London, 266: 1-13.

Blair-West, J.R., Coghlan, J.P., Denton, D.A., Goding, J.R., Wintour, M. and Wright, R.D. (1963). The control of aldosterone secretion. In: Plincus, S. (ed.) Recent Progress in Hormone Research. Academic Press, New York, pp. 311-383.

Block, E. (1994). Manipulation of dietary cation-anion difference on nutritionally related production diseases, productivity and metabolic responses in dairy cows. Journal of Dairy Science, 77: 1437-1450.

Bohra, H.C. and Ghosh, P.K. (1978). Effect of restricted water intake during summer on the digestability of cell wall constituents, nitrogen retention and water excretion in Marwari sheep. Journal of Agricultural Science Cambridge, 49: 605-608.

Bott, E., Denton, D.A., Goding, J.R. and Sabine, J.R. (1964). Sodium deficiency and corticosteroid secretion in cattle. Nature UK, 202: 461-463.

Brosh, A., Shkolnik, A, and Choshniak, I. (1986). Metabolic effects of infrequent drinking and low-quality feed on Bedouin goats. Ecology 67: 1086-1090.

Brouwer, E. (1965). Report of sub-committee on constants and factors. In: Proceeding of the 3rd International Symposium on Energy Metabolism of Farm Animals. Troon: EAAP Publ. 11: 441-443.

Campling, R.C., Freer, M. and Balch, C.C. (1961). Factors affecting the voluntary intake of food by cows. 2. The relationship between voluntary intake of roughages, the amount of digesta in the reticulo-rumen and the rate of disappearance of digesta from the alimentary tract. British Journal of Nutrition, 15: 531-536.

Cantrow, A. and Schepartz, B. (1957). Biochemistry. Vol. 2, Second Edition. W.B. Saunders Co. Philadalphia and London.

Carter, R.R. and Grovum, W.L. (1990). A review of the physiological significance of hypertonic body fluids on feed intake and ruminal function: salivation, motility and microbes. Journal of Animal Science, 68: 2811-2832.

Castle, M. E., A. Foot, and R. Holley. (1950). Some observations on the behaviour of dairy cattle with particular reference to grazing. Journal of Dairy Research, 17(3):215.

Chiy, P.C. and Phillips, C.J.C. (1993). Sodium fertilizer application to pasture. 1. Direct and residual effects on pasture production and composition. Grass and Forage Science, 48: 189-202.

Chiy, P.C. and Phillips, C.J.C. (1995). Sodium in forage crops. Sodium fertilization. In: Phlips, C.J.C and Chiy, P.C. (eds) Sodium in Agriculture. Chalcombe Publications, Canterbury, UK, pp. 43-81.

Christison, G. I. and Jonson, H. D. (1972). Cortisol turnover in heat-stressed cows. Journal of Animal Science, 35: 1005-1010.

Church, D.C., Smith, G.E., Fontenot, J.P. and Ralson, A.T. (1974). Water metabolism and requirements. In Digestive Physiology and Nutrition of Ruminants, vol. 2 (Nutrition). O ana B Books.

Clark, R. and Quin, J.L. (1949). Studies on the water requirements of farm animals in South Africa. 1. Effect of intermittent watering on merino sheep. Onderstepoort Journal of Veterinary Science, 22: 335-336.

Colditze, P.J. and Kellaway, R.C. (1972). The effect of diet and heat stress on feed intake, growth and N metabolism in Friesian, Brahman heifers, Australian Journal of Agricultural Research, 23: 717.

Cooper, K.E. (1966). Temperature regulation and the hypothalamus. British Medicine Bull., 22: 238-243.

Coppock, C.E. (1986). Mineral utilization by the dairy cow – chlorine. Journal of Dairy Science, 69: 595-603.

Cummings, D. (2002). Water quality for farm water supplies. Landcare Note LC 0089, 3pp. Department of Natural Resources and Environment, Melbourne.

Cyril, A.K. and Eric, N. (1971). The regulation of the constancy of the internal environment. In Samson Wright,s Applied Physiology, Twelfth Edition, pp. 1-59. Oxoford University Press, London.

Dmi'el, R. (1986). Selective sweat secretion and panting modulation in dehydrated goats. Journal of Thermal Biology, 11: 157-1 59.

Dmi'el, R. and Robertshaw, D. (1983). The control of panting and sweating in the black Bedouin goat: a comparison of two modes of imposing heat load. Physiology and Zoology, 56: 404-411.

Daws, G.T., and Squires, V.R. (1974). Observations on-the effects of temperature and distance to water on the behavior of Merino and Border Leicester sheep. Journal of Agricultural Science, (Cambridge), 82:383.

De Waal, H.O., Baard, M.A. and Engels, E.A.N. (1989). Effects of sodium chloride on sheep. 1. Diet composition, body mass changes and wool production in young Merino wethers grazing mature pasture. South African Journal of Animal Science, 19: 27-42.

Denton, D.A. (1982). The hunger for Salt: an Antbroplogical, Physiological and Medical Analysis. SpringeVerlag, Berlin.

Devendra, C. (1990). Comparative aspects of digestive physiology and nutrition in goats and sheep. In Ruminant Nutrition and Physiology in Asia (ed. C. Devendra and E. I mazumi) pp 45-60.

Devendra, C. and Burns, M. (1983a). Milk production. In: Goat Production Tropics. Pp. 64-73. Commonwealth Agriculture Bureaux.

Devendra, C. and Burns, M. (1983b). Reproductive performance. In: Goat production in Tropics. Pp. 75-89. Commonwealth Agriculture Bureaux.

Donald, C. and Betiz (2004). Carbohydrate metabolism. In: Dukes, Physiology of Domestic Animals. (Edited by Reece, W.O.), 12th Edition. Pp. 12-26. Comstock Publishing Associates Cornell University Press. Ithaca, London.

Dunson, W.A. (1974). Some aspects of salt and water balance of feral goats from arid island. American Journal of Physiology, 226: 662-669.

El Hadi, H.M., Dargie, J.D. and Hassan, Y.M. (1977). Water metabolism of desert sheep and goats under grazing and penned conditions. FAO/IAEA research coordination meeting on water requirements of tropical herbivores based on measurements with tritiated water.

El-Gawad, E. (1997). Physiological responses of Barki and Damascus goats and the crossbred to drinking saline water. Animal Production Research Institute, Ministry of Agriculture, Dogi, Cairo, Egypt, 42(1): 23-36.

El-Nouty, F.D., Yousef, M.K., Magdub, A.B. and Johnson, H.D. (1978). Thyroid hormones and metabolic rate in burros, Equus asinus, and llama, Lama glama : effects of environmental temperature, Comparison of Biochemistry Physiology, 60: 235.

Engell, D. (1988). Interdependency of food and water intake in humans. Appetite 10: 133-141.

English, P.B. (1966). Water and electrolytes balance in sheep (1) external balances of water, sodium, potassium and chloride. Research of Veterinary Science, 7: 233-257.

Evans, R.I. (1968). Manual and automated methods for measuring urea based on a modification of its reaction with diacetyl monoxime and thiosemicarbazide. Journal of Clinical Pathology, 21: 527-529.

Ferreira, A.V., Hoffman, L.C., Schoeman, S.J. and Sheridan, R. (2002). Water intake of Boer goats and Mutton merinos receiving either a low or high energy feedlot diet. Small Ruminant Research, 43: 245-248.

Fluharty, F.L., Loerch, S.C. and Dehority, P. (1996). Effects of feed and water deprivation on ruminal characteristics and microbial population of newly weaned and feedlot-adopted calves. Journal of Animal Science, 74: 465-474.

Forbes, R.M. (1968). The water intake of ewes. British Journal of Nutrition, 22: 33-43.

Freudenberger, D.O. and Hume I.D. (1993). Effects of water restriction on digestive function in two macropodid marsupials from divergent habitats and the feral goat. Journal of Comparative Physiology, 163(3):247-57.

Ganong, W. (2003). Energy balance, metabolism and nutrition. In: Review of Medical Physiology, pp. 282-319. Lange Medical Publications. Drawerl, Los/Altos, California.

Ganong, W. (2003). Renal function and micturition. In: Review of Medical Physiology, pp. 702-730. Lange Medical Publications. Drawerl, Los/Altos, California.

Gates, D.M. (1968). Physical environment. In: Adaptation of Domestic Animals. (edited by Hafez, E.S.E.) pp. 46-60. Lea and Febiger, Philadelphia.

Ghosh, T.K., Battacharya, B. and Moitra, D.N. (1983). Effects of short-term water deprivation on physiological performance and certain blood constituents in black Bengal goats. Indian Veterinary Journal, 60: 969-972.

Giger-Reverdin, S. and Gihad, E.A. (1991). Water metabolism and intake in goats. Chapter 4 in "Goat nutrition". Ed. Morand-Fehr, pp. 37-45. (Pudoc: Wageningen, Netherlands).

Gihad, E.A., Leith, H. and Al mason, A. A. (1993). Utalization of high salinity tolerant plants and saline water by desert animals. Towards the rational use of high salinity tolerant plants Vol. 1: Deliberations about high salinity tolerant plants and ecosystems. Proceeding of first ASWAS conference. December 8-15, 1990, Al Ain, United Arab Emarates: pp. 443-447. (Abstract).

Gihad, E.A. (1976). Intake, digestibility and nitrogen utilization of tropical natural grass hay by goats and sheep. Journal of Animal Science, 43: 879-883.

Gill, M., France, J., Summers, M., McBride, B.W. and Milligan, L.P. (1989). Simulation of the energy costs associated with protein turnover and Na+ K+-transport in growing lambs. Journal of Nutrition, 119: 1287-1299.

Goatcher, W.D. and Church, D.C. (1970). Taste responses in ruminants. IV. Reactions of pygmy goats, normal goats, sheep and cattle to acetic acid and quinine hydrochloride. Journal of Animal Science, 31: 373-382.

Godwin, I.R. and Williams, V.J. (1986). Effects of intraruminal sodium chloride infusion on rumen and renal nitrogen and electrolyte dynamics in sheep. British Journal of Nutrition, 56:379-394.

Grigg, G. C. and Seebacher, F. (1999). Field test of a paradigm: hysteresis of heart rate in thermoregulation by a free-ranging lizard (Pogona barbata). Proceedings of the Royal Society. London, 265: 1793–1799.

Grovum, W.L. and chapman, H.W. (1988). Factors affecting the voluntary intake of food by sheep. 4. The effect of additives representing the primary taste on sham intakes by oesophageally fistulated sheep. British Journal of Nutrition, 59: 63-72.

Hadjigeorgiou, I., Dardamani, K., Goulas, C. and Zervas, G. (2000). The effect of water availability on feed intake and digestion in sheep. Small Ruminant Research, 37: 147-150.

Hagsten, I., Perry, T.W. and Outhouse, J.B. (1975). Salt requirements of lambs. Journal of Animal Science, 42: 1187-1190.

Hales, J.R.S. and Webster, M.E.D. (1967). Respiratory function during thermal tachypnoea in sheep. The Journal of Physiology, London, 190: 241-260.

Hancock, J. (1953). Grazing behavior of cattle. Animal British Abstr. 21:1.

Harbers, L.H., Ames, D.R., Davis, A.B. and Ahmed M.B. (1975). Digestive responses of sheep to auditory stimuli. Journal of Animal Science, 41:654.

Harper, M.E., Willis, J.S. and Patrick, J. (1997). Sodium and chloride in nutrition. In: O'Dell BL, Sunde RA, eds. Handbook of Nutritionally Essential Minerals. New York: Marcel Dekker. 93-116.

Head, M.J. (1953). The effect of pregnancy and lactation in the ewe on the digestibility of the ration with a note on the partition of nitrogen in the foetus at full term. Journal of Agricultural Science, 43:214.

Heisey, S.R., Adams, T., Hofman, W. and Riogle, G. (1971). Thermally induced respiratory responses of the unanaesthetized goat. Respiratory Physiology, 11: 145-151.

Heller, V.G. and Paul, H. (1934). Effect of inorganic salt intake upon the mineral composition of blood. Journal of Biological Chemistry. 105: 655-661.

Hemsley, J.A., Hogan, J.P. and Weston, R.H. (1975). Effect of high intake of sodium chloride on the utilization of a protein concentrate by sheep. Australian Journal of Agricultural Research, 26: 715-727.

Henry, P.R. (1995) Sodium and chloride bioavailability. In: Ammerman, C.B., Baker, D.H. and Lewis, A.J. (eds) Bioavailability of Nutrients for Animals. Academic Press, New York, pp. 337-348.

Holtenius, K. and Dahlborn, K. (1990). Water and sodium movements across the ruminal epithelium in fed and food deprived sheep. Experimental Physiology, 75: 57.

Hossaini-Hilali, J., Benlamlih, S. and Dahlborn, K. (1994). Effects of dehydration, rehydration, and hyperhydration in the lactating and non-lactating black Moroccan goat. Comparative Biochemistry and Physiology, 109(4):1017-26.

Houpt, R.T. (2004). Water and electrolytes. In Dukes, Physiology of Domestic Animals. (Edited by Reece, W.O.), 12th Edition. Pp. 12-26. Comstock Publishing Associates Cornell University Press. Ithaca, London.

Hugo Eiler (2004). Endocrine gland. In Dukes, Physiology of Domestic Animals. (Edited by Reece, W.O.), 12th Edition. Pp. 621-669. Comstock Publishing Associates Cornell University Press. Ithaca, London.

Hungerford, T.G., (1990). Diseases of livestock. 9th Ed. (McGraw-Hill: Sydey). Jenkinson, D.Mc. and Robertshaw, D., (1971). Studies on the nature of sweat gland "fatigue" in the goat. Journal of Physiology, London, 212: 455-465.

Ittner, N., Kelly, C. and Guilbert, H. (1951). Water consumption of Hereford and Brahman cattle and the effect of cooled drinking water in a hot climate. Journal of Animal Science, 10:742.

Jenkinson, D.M. (1972). Evaporative temperature regulation in domestic animals. Symposium of the Zoological Society of London, 31: 345-356.

Johnson, H.D., Cheng, C.S. and Ragsdale, A.C. (1958). Environmental physiology and shelter engineering with special references to domestic rabbits. Research. Bull. Missouri. Agric. Exp. Stn., 640 (45): 648.

Jones, D.I.H., Miles, D.G. and Sinclair, K.B. (1967). Some effects of feeding sheep on low sodium hay with and without sodium supplement. British Journal of Nutrition, 21:391-397.

Kemp, A. (1971). The Effects of K and N Dressings on the Mineral supply of Grazing Animals. Proceedings of the 1st Colloquium of the Potassium Institute IBS, Wageningen, pp. 1-14.

Kerstin Olsson (2005). Fluid Balance in Ruminants: Adaptation to External and Internal Challenges Ann. N.Y. Acad. Science, 1040: 156–161. doi: 10.1196/annals.1327.020

Khalafalla, A.M. and Sulieman, Y.R. (1990). Some notes on the performance of Sudan Nubian and exotic goats in Sudan. Sudan Journal Animal Production, 3: 115-119.

Khan, M.A., Dickson, W.M. and Meyers, K.M. (1970). The effect of low environmental temperature on plasma corticosteroid and glucose concentrations in the newborn calf, Journal of Endocrinology, 48: 355.

Khan, M.S. and Ghosh, P.K. (1982). Comparative physiology of water economy in desert sheep and goats. Proceedings of the 3rd International Conference on Goat Production and Disease: 337. Dairy Goat Publishing Co., Scottsdale, USA.

Khan, M.S. and Ghosh, P.K. (1989). Physiological responses of desert sheep and goats to grazing during summer and winter. Indian Journal of Agricultural Science, 59: 600-603.

Khan, M.S., Ghosh, P.K. and Sasidharan, T.U. (1978). Effect of water restrictionon plasma proteins and on blood and urinary electrolytes in Barmer goats of the Rajasthan desert. Journal of Agricultural Science Cambridge, 91: 395-398.

Kimura, T., Abe, K. and Ota, K. (1986). Effect of hypertonic saline infusion and furosemide administration on atrial natriuretic peptide and vasopressin release in humans. Journal of Clinical Endocrinology Metabolism, 62: 1003-1010.

King, E.J. and Wooton, T.D.P. (1965). Determination of total protein in plasma or serum. In: Medical Biocemchemistry. Pp 138-450, Churchill Ltd., London.

King, J.M. (1983). Livestock water needs in pastoral Africa in relation to climate and forage. Research Report No.7. Int. Lives Centre Africa (ILCA), Addis Ababa, Ethiopia.

Knight, M. and Garcia, G.W. (1997). Characteristics of the goat (Capra hircus) and its potential role as a significant milk producer in the tropics: A review. Small Ruminant Research, 26: 203-215.

Langhans, W., Scharrer E. and Meyer A.H. (1991). Changes in feeding behavior and plasma vasopressin concentration during water deprivation in goats. Journal of Veterinary Medicine, A38: 11-20.

Leaf, A. (1962). The clinical and physiologic significance of the serum Na concentration. New England Journal Medicine, 267: 24-30.

Little, W., Samson, B.F., Manston R. and Allen, W.M. (1976). Effect of restricting the water intake of dairy cows upon their milk yield, body weight and blood composition. Animal Production, 22: 329-339.

Loosli, J.K. (1978). Sodium and chlorine requirements of ruminants. In: Conrad, J.H. and McDowell, L.R. (eds) Latin American Symposium on

Mineral Nutrition Research with Grazing Ruminants. Animal Science Department, University of Florida, Gainsville, pp. 54-58.

Macfarlane, W.V. and Howard, B. (1972). Comparative water and energy economy of wild and domestic mammals. Symposium of the Zoological Society of London, 31:261-279.

Macfarlane, W.V., Howard, B., Haines, P., Kennedy, J. and Sharpe, C.M. (1971). Hierarchy of water and energy turnover of desert mammals. Nature, 234: 483-484.

Maloiy, G.M.O. and Taylor, C.R. (1971). Water requirements of African goats and haired-sheep. Journal of Agricultural Science, Cambridge, 77: 203-208.

Maltz, E., Olsson, K., Glick, S.M., Fyhrquist, F., Silanikove, N., Chosniak, I. and Shkolink, A. (1984). Homeostatic response to water deprivation or hemorrhage in lactating and non-lactating Bedouin goats. Comparative Biochemistry and Physiology, 77A: 79-84.

Maltz, E., Silanikove, N. and Shkolnik, A. (1981). Renal performance in relation to water and nitrogen metabolism in Bedouin goats during lactation. Comparative Biochemistry and Physiology, 70A:145-147.

Martens, H. (1986). Blume I. Effect of intraruminal sodium and potassium concentrations and of the transmural potential difference on magnesium absorption from the temporarily isolated rumen of sheep. Quaternal Journal of Experimental Physiology, 71:409-415

Martine Steiger Burgos, Markus Senn, Franz Sutter, Michael Kreuzer, and Wolfgang Langhans. (2001). Effect of water restriction on feeding and metabolism in dairy cows. American Journal of Physiology Regulatory Integrative Comparative Physiology, 280 (2) : R418-R427.

McClymont, G.L., Wynee, K.N., Briggs, P.K. and Franklin, M.C. (1957). Growth response by sheep given high grain rations supplemented with sodium chloride. Austuralian Journal of Agricultural Research, 8:83.

McDowell, L.R. and Conard, J.H. (1993). Minerals for Grazing Ruminants in Tropical Regions. University of Florida. Gainesville. USA.

McDowell, R. E. and Weldy, J.R. (1967). Water exchange of cattle under heat stress. Biometeorology, 2:414.

McDowell, R.E. (1972). Improvement of Livestock Production in Warm Climates. W. H. Free- man and Co., San Francisco,

McDowell, R.E., Lee, D. B. and Forman, M. H. (1954). The measurement of water evaporation from limited areas of a normal body surface. Journal of Animal Science, 13: 405.

McGregor, B.A. (2004). Water quality and provision for goats. Rural Industries Research and Development Corporation (RIRDC), No 04/036, pp.63.

McGregor, B.A. (1984). Proceedings of a Workshop on "Improving Marketing and Returns from Goat Meat Production", Werribee. Nov. 1983 Agricultural Notes No. 137 pp.3-7 (Department of Agriculture, Melbourne).

McGregor, B.A. (1985). Complementary grazing of goats and sheep in the temperate zone. Proceedings of the 1st International Cashmere Conference, Canberra., pp. 103-23. (Australian Cashmere goat society: Melbourne).

McGregor, B.A. (1986). Water intake of grazing Angora wether goats and Merino wethers. Australian Journal of Experimental Agriculture, 26: 639-642.

McGregor, B.A. (1998). Nutrition, management and other environmental influences on the quality and production of mahaire and cashmere with particular reference to Mediterranean and annual temperate climatic zones: A review. Small Ruminant Research, 28: 199- 215.

McGregor, B.A. (2003). Nutrition of goats during drought. Rural Industries Research and Development Corporation. (RIRDC), No 03/016, pp.63.

McSweeney, C.S., Cross, R.B., Wholohan, B.T. and Murphy, M.R. (1988). Diagnosis of sodium status in small ruminants. Australian Journal of Agricultural Research, 39: 935-942

Meintjes, R.A. and Engelbrecht, H. (2004). Changes in the renal handling of urea in sheep on a low protein diet exposed to saline drinking water. Onderstepoort Journal of Veterinary Research.

Meyer, J.H., and Weir, W.C. (1954). The tolerance of sheep to high intakes of sodium chloride. Journal of Animal Science, 13: 443-449.

Michell, A.R. (1985). Sodium in health and disease: a comparative review with emphasis on herbivores. Veterinary Record, 116: 653-657.

Michell, A.R. (1995). Physiological roles for sodium in mammals. In: Phillips, C.J.C. and Chiy, P.C. (eds) Sodium in Agriculture. Chalcombe Publications, Caterbury, UK, pp. 91-106.

Michell, A.R., Moss, P., Hill, R., Vincent, I.C. and Noakes, D.E. (1988). The effect of pregnancy and sodium intake on water and electrolyte balance in sheep. British Veterinary journal, 144: 147-157.

Miles, W.H. and McDowell, L.R. (1983). Mineral deficiencies in the Llanos rangelands of Colombia. World Animal Review, 46:2.

Milligan, L.P. and Summers, M. (1986). The biological basis of maintenance and its relevance to assessing responses to nutrients. Proceedings of the Nutrition Society, 45: 185-193.

Minson, D.J. (1990). Forage in Ruminant Nutrition. Academic Press, New York, pp. 291-308.

Misra, A.K. and Khub, S. (2002). Effect of deprivation on dry matter intake, nutrient utilization and metabolic water production in goats under semi-arid zone of India. Small ruminant Research, 46: 159-165.

Mongin, P. (1981). Recent advances in dietary anion-cation balance applications in poultry. Proceedings of the Nutrition Society, 40: 285-294.

More, T. and Sahni, K.L. (1981). Effect of water intake on feed digestibility. World Review of Animal Production, 27:33-40.

More, T. and Sahni, K.L. (1978). Effect of long-term water deprivation on body weight and water intake of breeding ewes under semi-arid conditions. Journal Agricultural Science (Cambridge), 90: 435-439.

More, T., Howard, B. and Siebert, B.D., (1983). Effect of level of water intake on water energy and nitrogen balance and thyroxin secretion in sheep and goat. Australian Journal of Agricultural Research, 34: 441-446.

Morris, J.G. and Gartner, R.J.W. (1971). The sodium requirements of growing steers given an all-sorghum grain ration. British Journal of Nutrition, 25: 191-205.

Morris, J.G. and Peterson, R.G. (1975). Sodium requirements of lactating ewes. Journal of Nutrition, 105: 595-598.

Moseley, G. (1980). Effects of variation in herbage sodium levels and salt supplementation on the nutritive value of perennial ryegrass for sheep. Grass and Forage Science, 35: 105-113.

Murray, D. (1966). A comparison of cutaneous evaporation rates in cattle exposed to heat in a climate laboratory and in the field. Journal Agricultural Science, 66:175.

Murti, T.L. and Mullick, D.N. (1961). Seasonal variations of plasma and blood volumes in buffaloes. Annual of Biochemistry Experimental Medicine, 21: 91-96.

Musa, H.M. (1978). Some Biochemical Aspects of Dehydration in Camels, Desert Goats and Desert Sheep. M.V.Sc. Thesis University of Khartoum.

Musa, H.M. and Elkalifa, M.Y. (1992). Effects of water deprivation on dry matter intake, dry matter digestibility and nitrogen retention in Sudan desert lambs and kids. Small Ruminant Research, 6: 311-316.

Neathery, M.W., Blackmon, D.M., Miller, W.J., Heinmiller, S., McGuire, S., Tarabula, J.M., Gentry, R.F. and Allen, J.C. (1981). Chloride deficiency in Holstein calves from a low chloride diet and removal of abomasal contents. Journal of Dairy Science, 64: 2220-2233.

Nielsen, B. (1974). Actions of intravenous Ca^{++} and Na^{+} on body temperature in rabbits. Acta Physiologica Scandenavica, 90: 445-450.

NRC. (1981). Nutrient Requirements of domestic animals: No. 15. Nutrient Requirements of goats: Angora, Dairy, and Meat Goats in temperate and Tropical Countries. National Research Council. (National Academy Press: Washington DC) 91pp.

Ogebe, P.O., Ogunmodede, B.K. and McDowell, L.R. (1995). Performance of browsing West African dwarf kids fed graded levels of sodium supplements. Livestock Research For Rural Development, volume 7, number1.

Olsson, K. and Dahlborn, K. (1989). Fluid balance during heat stress in lactating goats. Quaternal Journal of Experimental Physiology, 74(5):645-59.

Olsson, K. and Hydbring, E. (1996). The preference for warm drinking water induces hyperhydration in heat-stressed lactating goats. Acta Physiologica Scandenavica, 157(1):109-114.

Olsson, K., Josater-Hermelin, M., Hossaini-Hilali, J., Cvek, K., Hydbring, E. and Dahlborn, K. (1996). Reproductive period affects water intake in heat-stressed dehydrated goats. Comparative Biochemistry and Physiology,, 113(4):323-31

Olsson, K. (1976). Influence of altered CSF solute composition on parotid salivary secretion in goats. Acta Physiologica Scandenavica, 97(2): 196-201.

Osman, H.E. and fadlalla, B. (1974). The effect of level of water intake on some aspects of digestion and nitrogen metabolism of the desert sheep of the Sudan. Journal Agricultural Science, 82: 61-69.

Panaretto, B. A. and Ferguson, K. A. (1969). Pituitary adrenal interaction in shorn sheep exposed to cold, wet conditions, Australian Journal of Agricultural Research, 20: 99.

Peirce, A.W. (1957). Saline content of drinking water for livestock. Veterinary reviews and Annotations, 3: 37-43.

Peirce, A.W. (1963). Studies on salt tolerance of sheep. Australian Journal of Agricultural Research, 14: 815-823.

Peirce, A.W. (1965). Studies on salt tolerance of sheep. 5. The tolerance of sheep for mixtures of sodium chloride, sodium carbonate and sodium bicarbonate in the drinking water. Australian Journal of Agricultural Research, 49: 815-823.

Polk, Charles and Elliot Postow, ed. (1995). Handbook of Biological Effects of Electromagnetic Fields. 2nd ed. CRC Press: Boca Raton, FL.

Potter, B.J. (1963). The effect of saline water on kidney tubular function and electrolyte execration in sheep. Australian Journal of Agricultural Research, 14: 518-528.

Potter, B.J. (1966). The effect of an interavenous infusion of hypertonic saline on renal mechanisms and on electrolyte changes in sheep. Journal of Physiology, London, 184: 605-617.

Potter, B.J. (1968). The influence of previous salt ingestion on the renal function of sheep subjected to intravenous hypertonic saline. Journal of Physiology, London, 194: 435-441.

Purohit, G.R., Ghosh, P.K. and Taneja, G.C. (1972). Water metabolism in desert sheep: effects of various degrees of water restriction on the distribution of body water in Marwari sheep. Australian Journal of Agricultural Research, 23: 685-691.

Qinisa, M.M. and Boomker, E.A. (1999). Effect of 50% water restriction on blood parameters of indigenous goats fed a low and a high nitrogen diet. South Africa Journal of Animal Science, 29: 23-24.

Ragsdale, A. C., H. J. Thompson, D. M. Worstell, and S. Brody (1950). Milk production and feed and water consumption responses of Brahman, Jersey, and Holstein cows to changes in temperature, 50° to 105°F and 50° to 8°F. Mo. Agricultural Experimental. Stn. Bull. 460.

Ray, D.E. and Wegner, T.N. (1989). Interrelationships among saline water ingestion, climate and cattle origin on feedlot performance of crossbred steers. Journal of Animal Science, 67 (2): 168.

Riond, J.L. (2001). Animal nutrition and acid-base balance. European Journal of Nutrition, 40: 245-254.

Robertshaw, D. (1966). Sweat gland functioning of the domestic ruminants. Proceeding 4th Biometeorology Cong. Rutgers, N.J.

Robertshaw, D. (1968). The pattern and control of sweating in the sheep and goat. Journal of Physiology, London, 198: 531-539.

Ross, E. (1979). The effect of water sodium on the chick requirement for dietary sodium. Poultry Science, 58: 626-630.

Roubicek, D. (1969). Water metabolism. pp. 353-373.

SAS. (1988). Statistical Analysis Systems Institute Inc. SAS procedures guide, release 6.03. Cary, NC.

Schmid-Nielsen, K. (1956). Animals and arid conditions. Physiological aspects of productive and management in the future of arid lands. American Association for the Advancement of Science, Washington, D.C., pp. 368-382.

Schmid-Nielsen, K. (1964). Rabbits and Jack rabbits in: Desert animals Physiological Problems of Heat and Water. pp. 129-138. Oxford University Press.

Schmid-Nielsen, K. (1972). Recent advances in the comparative physiology of desert animals. In: Comparative Physiology Of Desert Animals. (Ed. Maloiy, G.M.O). Academic Press, London.

Schoen, A. (1968). Studies on the water balance of the East African goat. East Africa Agricultural and Forestry Journal, 34, 256-262.

Scott, D. and Morton, J.J. (1976). Changes in urinary water and electrolyte excretion in sodium loaded sheep in response to intravenous infusion of arganine vasopression. Quaternal Journal of Experimental Physiology, 61: 57-70.

Senn, M., Gross-Lüem, S., Kaufmann, A. and Langhans, W. (1996). Effect of water deprivation on eating patterns of lactating cows fed grass and corn pellets ad lib. Physiology and Behavior, 60: 1413-1418.

Shapiro, Y., Epstein, Y., Horowitz, M. and Glick, S.M. (1986). The role of extrahypothalamic vasopression in thermoregulation. A hypothermical

model. Thermal Physiology Satellite Symposium of 30th International Congress of Physiological Science, pp. 102-115.

Shayakul, C., Smith, C.P., Mackenzine, H.S., Lee, W.S., Brown, D. and Hedger, A. (2000). Long term regulation of urea transporter depression by vasopressin in Brattleboro rats. American Journal of Physiology, 278:F620-F627.

Sheng, H.W. (2000). Sodium, chloride and potassium. In: Stipanuk M, ed. Biochemical and Physiological Aspects of Human Nutrition. Philadelphia: W.B. Saunders Company. 686-710.

Shirley, R.L. (1978). Water as a source of minerals. In: Conrad, J.H. and McDowell, L.R. (eds) Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. Animal Science Department, University of Florida, Gainsville, pp. 40-47.

Shkolnik, A. and Silanikove, N. (1991). Water economy, energy metabolism and productivity in desert ruminants. In: Nutrition and Systems of Goat Feeding, vol 1, ed Morand-Fehr, P., Borbouse, A. and De Simiane, M. pp 236-246. ITOVIC-INRA, Tours, France.

Shkolnik, A., Borut, A. and Choshniak, J. (1972). Water economy of the Bedouin goat. Symposium of the Zoological Society of London, 31: 229-242.

Sibanda, S., Hatendi, P.R., Mulenga, P.R. and Ndlovu, P. (1997). The effect of diet and frequency of watering on rumen degradability and outflow rate of low quality veld hay and dry matter apparent digestibility in steers given food at maintenance. Animal Science, 65: 159-164.

Siebert, B.D. and Macfarlane, W.V. (1975). Dehydration in desert cattle and camels. Physiology and Zoology, 48(1): 36-48.

Silanikove, N. and Tadmor, A. (1989). Rumen volume, saliva flow rate, and systemic fluid homeostasis in dehydrated cattle. American Journal of Physiology Regulatory Integrative Comparative Physiology, 256: R809-R815,

Silanikove, N. (1984). Renal excretion of urea in response to changes in nitrogen intake in desert (Black Bedouin) and non-desert (Swiss Saanen) goats. Comp. Biochem. Physiol. 79A: 651-654.

Silanikove, N. (1985). Effect of dehydration on feed intake and dry matter digestibility in desert (Black Bedouin) and non-desert (Swiss Saanen) goats fed on lucerne hay. Comparative Biochemistry and Physiology, 80A: 449-452,

Silanikove, N. (2000). The physiological basis of adaptation in goats to harsh environments. Small Ruminant Research, 35: 181-193.

Silanikove, N. (1986a). Interrelationships between feed quality, digestibility, feed consumption, and energy requirements in desert (Bedouin) and non-desert (Saanen) goats. Journal of Dairy Science, 69: 2157-2162.

Silanikove, N. (1986b). Feed utilization, energy and nitrogen balance in desert black Bedouin goats. World Review Animal Production, 22: 93-96.

Silanikove, N. (1987a). Impact of shade in a hot Mediterranean summer on feed intake, feed utilization and body fluid distribution in sheep. Appetite. 9: 207-215.

Silanikove, N. (1987b). Effect of imposed reduction in energy intake on resting and fasting heat production in the black Bedouin Goat. Nutrition Report International, 35: 725-731.

Silanikove, N. (1989). Inter-relationship between water, food and digestible energy intake in desert and temperate goats. Appetite, 12:163-170.

Silanikove, N. (1992). Effect of water scarcity and hot environment on appetite and digestion in ruminants: a review. Livestock Production Science, 30:175-194.

Silanikove, N. (1994). The struggle to maintain hydration and osmoregulation in animals experiencing severe dehydration and rapid rehydration: the story of ruminants. Experimental Physiology, 79: 281-300.

Silanikove, N., Tagari, H. and Shkolnik, A. (1993). Comparison of rate passage, fermentation rate and efficiency of digestion of high fiber diet in desert black Bedouin goats as compared to Swiss Saanen goats. Small Ruminant Research, 12: 45-60.

Silanikove, N; Tagari, H. and Shkolnik, A. (1980). Gross energy digestion and urea recycling in the desert black Bedouin goats. Comparative Biochemistry and Physiology, 67A: 215-218.

Singh, N.P., More, T. and Sahni, K.L. (1976). Effect of water deprivation on feed intake, nutrient digestibility and nitrogen retention in sheep. Journal of Agricultural Science, Cambridge, 86:431-433.

Sinton, L.W., Finlay, R.K. and Lynch, P.A. (1999). Sunlight inactivation of fecal bacteriophages and bacteria in sewage-polluted seawater. Applied and Environmental Microbiology, 65: 3605-3613.

Sinton, L.W., Hall, C.H., Lynch, P.A. and Davies-Colley, R.J. (2002). Sunlight inactivation of fecal indicator bacteria and bacteriophages from waste

stabilization pond effluent in fresh and saline waters. Applied and Environmental Microbiology, 68: 1122-1131.

Smith, G.S. and Middleton, K.R. (1978a). A classification of pasture and fodder species according to their ability to translocate sodium from their roots to aerial parts. New Zealand Journal of Experimental Agriculture, 6: 183-188.

Smith, G.S. and Middleton, K.R. (1978b). Sodium and potassium content of topdressed pastures in New Zealand in relation to plant and animal nutrition. New Zealand Journal of Experimental Agriculture, 6, 217-225.

Sonnenberg, H. (1990). Mechanisms of release and renal action of atrial natriuretic peptide. Acta Physiologica Scandenavica, 138 (591):80-87.

Stefan Puschmann and Claus Jessen (1978). Anterior and posterior hypothalamus: Effects of independent temperature displacements on heat production in conscious goats. Pflügers Archive European Journal of Physiology, 373 (1): 59 - 68.

Steiger Burgos, M., Langhans, W. and Senn, M. (2000). Role of rumen fluid hypertonicity in the dehydration-induced hypophagia of cows. Physiology and Behavior, 71: 423-430.

Suttle, N.F. and Field, A.C. (1967). Studies on magnesium in ruminant nutrition. Effect of increased intakes of potassium and water on the metabolism of magnesium, phosphorus, sodium, potassium, and calcium in sheep. British Journal of Nutrition, 21: 819-831.

Taubes, G. (1998). The (political) science of salt. Science, 281(5379):898-901.

Thomas, B., Thompson, A., Oyenuga, V.A. and Armstrong, R.H. (1952). The ash constituents of some herbage plants at different stages of maturity. Empire Journal of Experimental Agriculture, 20: 10-22.

Thomson, G.E. (1973). Review of the progress of dairy science. Climatic physiology of cattle. Journal of Dairy Research, 40: 441.

Thornton, S.N., Baldwin, B.A. and Purdew, T. (1985). Osmotically induced drinking in the goat: an osmoreceptor or a sodium receptor mechanism? Quaternal Journal of Experimental Physiology, 70(4):549-56.

Thwaites, C.J., Baillie, N.B. and Kasa, W. (1990). Effect of dehydration on the heat tolerance of male and femal. New Zealand white rabbits. Journal Agricultural Science, Cambridge, 115: 437-440.

Tisserand, J.L., Hadjipanayiotou, M. and Gihad, E.A. (1991). Digestion in Goats. Chapter 5 in Goat Nutrition, ed. P. Morand-Fehr, Pudoc Wageningen.

Tomas, F.M., Jones, G.B., Potter, B.J. and Langsford, G.L. (1973). Influence of saline drinking water on mineral balances in sheep. Australian Journal Research, 24: 377-386.

Turner, J. (1979). Osmotic fragility of desert bighorn sheep red blood cells. Comparative Biochemistry and Physiology, 64(A): 167-175.

Umunna, N.N., Chineme, C.N., Saror, D.I., Ahmed, A. and Abed, S. (1981). Response of Yankasa sheep to various lengths of water deprivation. Journal of Agricultural Science, Cambridge, 96: 619-622.

Underwood, E.J and Suttle, N.F. (1999). The mineral nutrition of livestock. 3rd Ed. CABI Publishing, New York.

Valtorta, S., Hahn, L. and Johnson, H. D. (1982). Effect of high ambient temperature (35°C) and feed intake on plasma T4 levels in sheep. Proceedings of the Society Experimental. Biology and Medicine, 169: 260.

Van Kampen, M. (1974). Physical factors affecting energy expenditure. In Morris, T. R. and Freeman, B. M. eds., Energy Requirements of Poultry. British Poultry Science Ltd., Edinburgh.

Weeth, H.J. and Lesperance, A.L. (1965). Renal function of cattle under various water and salt loads. Journal of Animal Science, 24: 441.

Weeth, H.J., Haverland, L.H. and Cassard, D.W. (1960). Consumption of sodium chloride water by heifers. Journal of Animal Science, 845-848.

Weeth, H.J.and Haverland, L.H. (1961). Tolerance of growing cattle for drinking water containing sodium chloride. Journal of Animal Science, 20: 518.

Weir, W.C. and Miller, R.F. (1953). The use of salt as a regula-tor of protein supplement intake by breeding ewes. Journal of Animal Science, 12:218-225

Wesson, L.G. (1969). Physiology of Human Kidney. Grane and Stratton, New York.

Whitlock, R.H., Kessler, M.J. and Tasker, J.B. (1975) Salt (sodium) deficiency in dairy cattle: polyuria and polydypsia as prominent clinical features. Cornell Veterinarian, 65: 512-526.

William O. Reece (2004). Kidney function in mammals In Dukes, Physiology of Domestic Animals. (Edited by Reece, W.O.), 12th Edition. Pp. 73-

106. Comstock Publishing Associates Cornell University Press. Ithaca, London

William, O. Reece and Melvin, J. Swenson (2004). The composition and functions of blood. In Dukes, Physiology of Domestic Animals. (Edited by Reece, W.O.), 12th Edition. Pp. 26-52. Comstock Publishing Associates Cornell University Press. Ithaca, London.

Wilson, A.D. (1966). The tolerance of sheep to sodium chloride in food or drinking water. Australian Journal Agricultural Research, 17:503-514.

Wilson, A.D. and Hindley, N.L. (1970). Variation in the performance of sheep when introduced to saline drinking water. CSIRO Aust. Fld. Stn. Rec. Div. Plant Ind., 9:45-53.

Wilson, A.D. (1968). The effect of high salt intake or restricted water intake on diet selection by sheep. British Journal of Nutrition, 22: 583-599.

Wilson, R.T. (1989). Ecophsiology of the Camelidae and Desert Ruminants. Springer- Verlag, Berlin, 120 pp.

Winchester, C.F. and M.J. Morris. (1956). Water intake rates of cattle. Journal of Animal Science, 15:722.

Wittenberg, C., Chosniak, I., Shkolnik, A., Thurau, K. and Rosenfeld, J. (1986). Effect of dehydration and rapid rehydration on renal function and on plasma renin and aldosterone levels in the black Bedouin goat. Pflüg. Arch., 406: 405-408.

Wooton, T.D.P. (1974). Plasma sodium and potassium microanalysis. In:Medical Biochemistry. Pp. 62-62, Fifth Edition. Academic Press, London.

Yeates, N.T.M. (1965). Modern Aspects of Animal Production. Pp. 89-98. Butterworths, London.

Young, B.A. (1976). Cold stress as it affects animal production. Journal of Animal Science, 56: 699.

Yousef, M.K. and Johnson, H.D. (1965). Time course of thyroxine disappearance rates in cattle during exposure to hot and cold environments. Life Science, 4: 1531.

Yousef, M.K. and Johnson, H.D. (1967). A rapid method for estimation of thyroxine secretion rate of cattle, Journal of Animal Science, 26: 1108.

Zucker, A., Gleason, S.D. and Schneider, E.G. (1982). Renal and endocrine responses to water deprivation in dog. Am. J. Physiol., 242. Regulatory Integrative Comparative Physiology, (11): R 296-R 302.

Appendix

A_1: Water balance of Yankasa sheep and Maradi goats

	Species		SE[1]
	Sheep	**Goats**	
Number of animals	4	4	
Average live weight *(kg)*	25.56	20.16	0.25
Metabolic mass *($kg^{0.73}$)*	10.95	8.96	0.08
Water drunk *($ml/kg^{0.73}/day$)*	202.53	152.4[2]	8.14
Water intake in food *($ml/kg^{0.73}/day$)*	3.17	2.75	0.03
Metabolic water *($ml/kg^{0.73}/day$)*	19.02[3]	16.95[2]	0.36
Water loss in faeces *($ml/kg^{0.73}/day$)*	16.08[3]	9.32[2]	0.84
Water loss in urine *($ml/kg^{0.73}/day$)*	45.60	42.0	2.07
Evaporated water loss *($ml/kg^{0.73}/day$)*	162.40[3]	120.40[2]	6.74
Average daily urine production *(ml)*	501.1	382.9	9.16
Daily water intake *(ml)*	2218.0	1364.0	68.79
Daily hay intake *(g)*	500.0	375.0	
Average daily faecal output *(g)*	362.1	208.8	10.92

1 Standard error.
2,3 Means within the same variable bearing different superscript differ ($P<0.01$).

A_2: Estimated daily drinking water requirements for non-lactating livestock under African ranching conditions.

		Daily drinking water requirement (1)		
Species	**Weight (kg)**	**Mean**	**Theoretical maximum**	**Practical guideline for development**
Goat	30	2.0	5.4	5.0
Sheep	35	1.9	5.2	5.0
Zebu bovine	350	16.4	56.1	25.0
Camel	500	18.4	34.0	30.0 (est.)

Source: Barrett and Larkin (1974); Classen (1977); King (1979).

A_3: The relative contributions (%) of sweating and panting to evaporative heat loss in various domestic animals in a hot, dry environment.

	Relative contribution (%) to evaporative heat loss					
	Donkey	**Camel**	**Cow**	**Sheep/goat**	**Dog**	**Pig**
Sweat	100	95	65	40	10	0
Pant	0	5	35	60	90	100

Source: Jenkinson (1972).

A_4: Average composition of milk from indigenous arid-adapted Ethiopian livestock and temperate-type cattle.

Constituent	Milk composition (%)				
	Barka cattle	Adal goats	Adal sheep	Adal camels	Temperate-type cattle
Moisture	86.1	88.2	86.4	85.6	87.6
Ash	0.6	0.6	0.6	0.9	0.7
Protein	3.8	3.3	4.4	4.5	3.2
Ether extract	5.0	2.9	4.1	5.5	5.4
Carbohydrate	4.5	2.8	3.7	3.4	4.8

Source: Knoess (1977); Williamson and Payne (1978

A_5: Tolerances of livestock to total dissolved solids (salinity) in drinking water (mg/L)

Livestock	No adverse effects on animals expected	Animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production.	Loss of production and decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually.
Beef cattle	0–4000	4000–5000	5000–10 000
Dairy cattle	0–2500	2500–4000	4000–7000
Sheep	0–4000	4000–10 000	10 000–13 000[(a)]
Horses	0–4000	4000–6000	6000–7000
Pigs	0–4000	4000–6000	6000–8000
Poultry	0–2000	2000–3000	3000–4000

(a) Sheep on lush green feed may tolerate up to 13 000 mg/L TDS (total dissolved solids) without loss of condition or production.
Reference: Anzecc and Armcanz (2000), adapted from Anzecc (1992).

A_6: Tolerance of salty drinking water by different livestock species.

Species	% total salts in drinking water
Camel	5.5
Goat	1.5
Sheep	1.3-2.0
Cow	1.0-1.5
Donkey	1.0
Horse	0.9
Pig	0.9

Source: French (1956a), Wilson (1967, Macfarlane (1971); Maloiy (1972).

A_7: The threshold for rejection and acceptance of test solutions for different taste responses for British dairy goats. Rejection determined if ≤ 20% of water intake was the test solution. Acceptance determined if > 40% of water intake was the test solution (adapted from Bell 1959)

Taste	**Test solution**	**Threshold**		Peak intake of solution
		Acceptance	**Rejuction**	
Bitter	Quinine dihydrochloride	12.5 mg/100ml	125 mg/100 ml	**3-6 mg/100 ml**
Salt	Sodium chloride	1.25 g/100 ml	5 g/100 ml	**0.08-1.25 g/100 ml**
Sweet	D- glucose	10 g/100 ml	> 40 g/100 ml	**0.32-5 g/100ml**
Sour	**Acetic acid**	**1.25 ml/100 ml**	**5 ml/100 ml**	**0.04-0.6 ml100 ml**

For salty tastes, at dilutions below the acceptance threshold, goats preferred water over fresh water. Dilutions of the other taste solutions below the acceptance level were all preferred over fresh water.

A_8: Safe levels of toxic elements and ions in livestock drinking water.

Element	Level (mg. l^{-1})	Remarks
Arsenic (as As)	1.0	Inorganic oxide, especially from dips
Boron (as B)		Present at < 4 mg.l^{-1}, whereas 450 mg.l^{-1} inhibits growth
Cadmium (as Cd)	0.01	Accumulates in liver and kidneys
Calcium (as Ca)	1000	<700 mg.l^{-1} desirable for beef, esp. if Mg present
Chromium (as Cr)	1-5.0	Industrial effluent, but not readily absorbed
Copper (as Cu)	0.5-2.0	Essential trace element, but could reach toxic level from wide agricultural use
Fluoride (as F)	2.0	See text
Iron (as Fe)	10.0	Scouring caused by grazing pasture irrigated with high-Fe water
Lead (as Pb)	0.5	Cumulative poison
Magnesium (as Mg)	250-500	Predisposes to rickets if Ca content low, sulphate causes scouring
Mercury (as Hg)	0.002	Health hazard to human beings consuming meat
Molybdenum (as Mo)	0.01	Only dangerous if accumulated in (irrigated) pasture
Nitrate (as NO_3)	90-200	Sources are deep wells filled by seepage from highly fertile soil, or dams containing much decaying organic matter, e.g. manure
Selenium (as Se)	0.02	To compensate for plant ability to concentrate Se
Sulphate (as SO_4^{2-})	1000	High magnesium sulphate causes severe problems
Zinc (as Zn)	20	Natural and industrial contamination, but

		relatively non-toxic

Source: Hart (1974).

A_9: Mean (SD) sodium concentrations (g /kg DM) in pastures and foodstuffs mostly from the Uk (from MAFF, 1990) and chloride concentrations for corresponding foodstuffs from the USA (NRC as quoted by McDowell, 1992).

	Na	Cl		Na	Cl		Na	Cl
Herbage	2.5 (2.1)	4-	Fish-meal	11.2	-	Fodder beet	3.0	-
Grass hay	2.1 (1.7)	6	Soybean	(1.5)	0.4	Swedes	(1.6)	
Grass	2.7 (1.6)		meal (ext)	0.2	1.3	Turnips	0.7a	
silage	0.8 (0.5)	-	Salfflower	(0.1)	-	Cassava	2.0a	-
Clover	1.3 (1.0)	-	meal	1.0	1.0	meal	0.6	8-12
silage	0.3 (0.2)	4.1	Palm-	(1.2)	-	Meat and	(0.3)	16.4
(mix)	2.1 (1.7)	1.8	kernel cake	0.2	0.5	bone meal	8.0	31.0
Lucerne	0.6 (0.1)	4-	Maize	(0.1)	0.4	Molasses	(1.0)	
(alfaalfa)	2.8 (1.6)	5	gluten	2.6	0.5	(beet)	25.0	0.4
silage	1.3 (0.8)	3.0	Rapeseed	(1.4)	1.8	Molasses	(8.2)	1.7
Maize	1.3 (1.4)	-	meal	0.4	0.5	(cane)	1.2	0.5
silage	0.6 (1.0)	4.8	Cottonseed	(0.3)	1.1	Molassesed	(0.9)	
Grass hay	32.0(10.5)	6.7	meal	0.2	1.0	beet pulp	4.4	-
Lucerne		3.2	Linseed	(0.2)		Beet pulp	(0.3)	-
(alfalfa)		-	meal	0.7		Brewers	3.2	
hay			Maiz	(0.0)		grains	(2.1)	
Dried			Barley			Wheat feed	0.3	
grass			Wheat	0.3		Distillers	(0.3)	
Dried			Oats	(0.4)		grains:	0.1	
Lucerne			Sorgam	0.1		Wheat	(0.1)	
(alfalfa)				(0.1)		Barley		
Barley				0.2			3.1	
straw				(0.1)			(3.9)	
Wheat				0.5			0.3	
straw				(00)			(0.3)	
Alkali-								
treated								
barley								
straw								

a New Zealand data from cornforth etal. (1978).
SD, Standard deviation.

بسم الله الرحمن الرحيم

ملخص الأطروحة

تمت دراسة تأثيرات ملوحة ماء الشرب ، إيقاف استهلاك الماء (Water deprivation) والتغيرات الفصلية فى البيئة الحرارية المدارية على الاستجابات الفسيولوجية للماعز النوبى.

فى التجربة الأولى تمت دراسة تأثير الارتفاع المتدرج لتركيز ملح كلوريد الصوديوم (0.8، 1.2، 1.6، 2%) فى ماء الشرب على الإستجابات الفسيولوجية للماعز النوبي خلال فصلى الصيف والشتاء. أوضحت التجربة أن درجة حرارة المستقيم (Tr) لم تتأثر بملوحة ماء الشرب ، أما معدل التنفس (RR) فقد ازداد معنويا فى كل المجموعات التى استهلكت ماء الشرب المالحة خلال فصل الصيف عند 2:30 مساء مقارنة مع المجموعات المقابلة لها التى استهلكت ماء الحنفية. قيم درجة حرارة المستقيم ومعدل التنفس كانا أعلى فى فصل الصيف كما أوضحت نظما يوماويا.

فى كلا الفصلين معدل استهلاك الماء كان أعلى فى المجموعات التى استهلكت ماء الشرب المالحة مقارنة مع قيم المجموعات المقابلة لها التى استهلكت ماء الحنفية، كما ان ازدياد تركيز كلوريد الصوديوم فى ماء الشرب من 0.8 الى 1.2% ادى الى ازدياد استهلاك الماء ، اما عند ازدياد تركيز كلوريد الصوديوم الى 2% انخفض استهلاك الماء. كمية كلوريد الصوديوم المتناول من استهلاك ماء الشرب المالحة ازداد معنويا مع ازدياد تركيز كلوريد الصوديوم. تراكيز كلوريد الصوديوم العالية (1.6 و 2%) فى ماء الشرب ادى الى انخفاض معنوى فى كمية الغذاء المستهلك بواسطة الماعز. متوسط تغير وزن الجسم انخفض معنويا فى المجموعة التى استهلكت 1.6% من ملح كلوريد الصوديوم خلال فصل الصيف مقارنة مع المجموعة المقابلة لها التى استهلكت ماء الحنفية.

مكداس الدم خلال فصل الصيف اقل فى المجموعات التى استهلكت 1.2 و 1.6% من ملح كلوريد الصوديوم مقارنة مع المجموعات المقابلة لها التى استهلكت ماء الحنفية. أعلى قيمة لمكداس الدم والهيموغلوبين للمجموعات التى استهلكت ماء الشرب المالحة سجلت خلال الشتاء فى المجموعة التى استهلكت 2% من ملح كلوريد الصوديوم فى ماء الشرب. تركيز الجلوكوز فى البلازما لم يتأثر معنويا بإستهلاك ماء الشرب المالحة فى كلا الفصلين، لكن متوسط تركيز الجلوكوز فى فصل الشتاء اعلى قليلا فى كلا المجموعتين مقارنة مع فصل الصيف.

تراكيز البروتين الكلى والالبيومين فى السيرم ارتفعت معنويا بازدياد تركيز كلوريد الصوديوم فى ماء الشرب خلال فصل الشتاء. كما كانت اعلى فى المجموعات التى استهلكت 1.2، 1.6، و 2% من كلوريد الصوديوم مقارنة مع المجموعات المقابلة لها التى استهلكت ماء الحنفية فى كلا الفصلين. فى كلا الفصلين، تركيز اليوريا فى السيرم انخفض معنويا فى المجموعات التى استهلكت تراكيز عليا من كلوريد الصوديوم (1.6 و 2%) مقارنة مع التراكيز المنخفضة. الزيادة التدريجية لتركيز كلوريد الصوديوم فى ماء الشرب ادت لازدياد تدرجى معنوى فى تركيز الصوديوم فى السيرم خلال فصل الصيف، ولكن هذه الزيادة التدريجية

لتركيز كلوريد الصوديوم فى ماء الشرب أدت الى انخفاض تدريجى معنوى للبوتاسيوم فى السيرم فى كلا الفصلين.أما تركيز الماغنزيوم فى السيرم لم يتأثر بهذه الزيادة التدريجية لكلوريد الصوديوم فى كلا الفصلين.

تركيز اليوريا فى البول ازداد معنويا مع ازدياد تركيز كلوريد الصوديوم فى ماء الشرب فى كلا الفصلين. قيم تركيز اليوريا أعلى فى المجموعات التى استهلكت ماء الشرب المالحة مقارنة مع المجموعات المقابلة لها التى استهلكت ماء الحنفية فى كلا الفصلين. تركيز الصوديوم فى البول ازداد معنويا مع ازدياد تركيز كلوريد الصوديوم فى ماء الشرب. تركيز الصوديوم أعلى فى المجموعات التى استهلكت ماء الشرب المالحة مقارنة مع المجموعات المقابلة لها التى استهلكت ماء الحنفية خلال فصل الصيف. وأيضا تركيز البوتاسيوم فى البول ازداد معنويا مع ازدياد تركيز كلوريد الصوديوم فى ماء الشرب. تركيز الصوديوم أعلى فى المجموعات التى استهلكت ماء الشرب المالحة مقارنة مع المجموعات المقابلة لها التى استهلكت ماء الحنفية خلال فصل الشتاء. اما تركيز الماغنيزيوم فى البول فقد ازداد معنويا مع ازدياد تركيز كلوريد الصوديوم فى ماء الشرب فى فصل الصيف.

فى التجربة الثانية تمت دراسة التأثير المشترك لملوحة ماء الشرب (1.2% كلوريد صوديوم) مع إيقاف استهلاك الماء (Water deprivation) على الإستجابات الفسيولوجية للماعز النوبي خلال فترة الصيف الرطب. أوضحت التجربة أن التاثير المشترك لملوحة ماء الشرب وإيقاف استهلاك الماء أدى الى ازدياد معنوي فى درجة حرارة المستقيم للماعز والتى انخفضت بعد إعادة الإماهة (Rehydration) فى المجموعة التى استهلكت ماء الشرب المالحة. معدل التنفس إزداد معنويا فى اليوم الأول من إيقاف استهلاك الماء ولكن انخفض معنويا فى اليوم التالى منه.

ملوحة ماء الشرب ادت الى ارتفاع معدل استهلاك الماء مقارنة مع قيم المجموعات المقابلة لها التى استهلكت ماء الحنفية. فى اليوم الأول من إعادة الإماهة، معدل استهلاك الماء ازداد معنويا فى كلا المجموعتين مقارنة مع القيم عند بداية التجربة، مع أن معدل استهلاك الماء كان أعلى معنويا فى المجموعة التى استهلكت ماء الشرب المالحة مقارنة مع المجموعة المقابلة لها التى استهلكت ماء الحنفية. إيقاف استهلاك الماء أدى إلى انخفاض معدل استهلاك الغذاء فى كلا المجموعتين لكن هذا الإنخفاض فى معدل استهلاك الغذاء كان معنويا فقط فى المجموعة التى استهلكت ماء الحنفية. استهلاك 1.2% من ملح كلوريد الصوديوم فى ماء الشرب لم يؤثر على معدل استهلاك الغذاء مقارنة مع المجموعة التى استهلكت ماء الحنفية.

لم يتأثر مكداس الدم وتركيز الهيموغلوبين بإستهلاك ماء الشرب المالحة، لكن إيقاف استهلاك الماء أدى لإرتفاعهما فى كلا المجموعتين. بعد يومين من إعادة الإماهة مكداس الدم والهيموغلوبين عادا الى مستوى القيم عند بداية التجربة. تركيز الجلوكوز فى البلازما مال إلى الإنخفاض خلال فترة إقاف استهلاك الماء فى كلا المجموعتين.

التأثير المشترك لملوحة ماء الشرب وإيقاف استهلاك الماء أدى الى ارتفاع معنوى فى تركيز البروتين الكلى ، الالبيومين واليوريا فى السيرم. تراكيز البروتين الكلى والألبيومين للمجموعة التى استهلكت ماء الشرب المالحة لا تختلف معنويا مقارنة مع المجموعات المقابلة لها التى استهلكت ماء الحنفية. أما تركيز

اليوريا فى المجموعة التى استهلكت ماء الشرب المالحة ارتفع معنويا مقارنة مع قيم المجموعات المقابلة لها التى استهلكت ماء الحنفية.

تركيز الصوديوم فى السيرم أعلى فى المجموعة التى استهلكت ماء الشرب المالحة مقارنة مع قيم المجموعة المقابلة لها التى استهلكت ماء الحنفية خلال فترة استهلاك الماء الطبيعية (Normal hydration) . أما تركيز البوتاسيوم فى السيرم أعلى فى المجموعة التى استهلكت ماء الشرب المالحة مقارنة مع قيم المجموعة المقابلة لها التى استهلكت ماء الحنفية خلال فترة استهلاك الماء الطبيعية وعند إعادة الإماهة. تركيز الماغنزيوم فى السيرم أعلى فى المجموعة التى استهلكت ماء الشرب المالحة فى اليوم الثانى من إيقاف استهلاك الماء وخلال فترة إعادة الماء.

النتائج التى تم عرضها فى هذه الرسالة عن الماعز النوبي تمت مناقشتها ومقارنتها مع المعلومات المتوفرة من الدراسات السابقة للماعز والحيوانات المنزلية الأخرى.